Joondalup Coastal Foreshore Natural Areas Management Plan

City of Joondalup

Prepared by:

Ecoscape (Australia) Pty Ltd
9 Stirling Hwy PO Box 50
North Fremantle 6159
Telephone: (08) 9430 8955 Facsimile: (08) 9430 8977
ecoscape@iinet.net.au
www.ecoscape.com.au

REPORT FOR CITY OF JOONDALUP
JOONDALUP COASTAL FORESHORE NATURAL AREAS MANAGEMENT PLAN
COPYRIGHT STATEMENT 2002
ECOSCAPE (AUSTRALIA) PTY LTD
ABN 70 070 128 675

Direct all inquiries to:

Ecoscape (Australia) Pty Ltd
9 Stirling Hwy PO Box 50
North Fremantle WA 6159
Ph: (08) 9430 8955 Fax: (08) 9430 8977
ecoscape@iinet.net.au

Table of Contents

Joondalup Coastal Foreshore Natural Areas Management Plan

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Acknowledgments

Joondalup Coastal Foreshore Natural Areas Management Plan

Ecoscape wishes to thank all those who have given assistance in the preparation of this report. We would particularly like to thank the following people and groups:

- The City of Wanneroo, particularly Phil Calley and Daniel Lenferna for providing information on maintenance strategies for their city;
- The City of Stirling, in particular Molly Steele, Daniel Rajah and Tanja Lamb for providing assistance with research;
- The Town of Cambridge, in particular Ross Bowman and the CEO's office for providing information on maintenance strategies for their city;
- The Joondalup Community Coastcare Forum, particularly Mike Norman for information and comments; and
- Coastcare, especially Julie Kennedy for providing information related to Coastcare grants in the City of Joondalup.
- Individuals and organisations that gave permission to reproduce their images of weeds shown in Appendix One, or assisted in arranging contact with individuals, including:
  - Sam Wilson of University of Western Australia Press;
  - Elizabeth Rippey;
  - Ben Richardson of CALM, who is involved with the online database Flora Base;
  - Rod Randall of Agriculture Western Australia;
  - John Dodd of Agriculture Western Australia;
  - Coralie Hortin of the Albany CALM Regional Herbarium;
  - Stan Armstrong;
  - Keith Eddington;
  - Mack Seale;
  - Kym Lego; and
  - Brenda Mowe.
- Ecoscape casual staff Kelli O'Neill, for assistance in the field and for her photographs, and Brian Naylor, for assistance with creating the maps.

Ecoscape would also like to thank the City of Joondalup, particularly the following people for assistance and valuable information:

- Dennis Cluning;
- Keith Armstrong;
- Craig Johnson;
- Wayne Grimes;
- Rob Augustine.

Summary

Joondalup Coastal Foreshore Natural Areas Management Plan

The City of Joondalup coastal foreshore represents an important regional resource that requires appropriate management in order to sustain it over time. Most of the foreshore has regional conservation value, with significant areas of coastal limestone cliffs, coastal heathland, landscape values such as high dunes, and acting as a regional green corridor. Increasing pressure on the coastal reserves could result in significant changes to the structure and function of the coastal ecosystem, as well as to the aesthetic value and recreation amenity of the area. This report presents the results of a study into the current condition of the coastal vegetation and dunes, and the optimum management and maintenance framework to preserve and enhance the conservation value of the coastal foreshore vegetation.

Study Area

The study area included all areas of vegetation within the coastal foreshore area managed by the City of Joondalup. The waste water treatment area in Ocean Reef and the Whitfords Nodes area (both part of *Bush Forever* Site 325) and Hillarys Boat Harbour were excluded from the study area. The study are stretches approximately 14 km from Burns Beach to Marmion Beach, totalling 239 ha in area. Locations within the study area include Iluka Foreshore, Ocean Reef, North Mullaloo, the "Pinnacles", Mullaloo Beach, Whitfords Beach, Hillarys Beach, Sorrento Beach and Marmion Beach.

Existing Environment

Coastal Processes

The coastline within the study area continues to undergo change related to long-term changes in sea level. Sand is still being supplied to the coast, offshore reefs are undergoing erosion, and the shape of sandy parts of the coast continue to change in response to changes in sand supply and wave direction (Woods, 1984b). Sandy coasts around beach ridge plains are present between Sorrento Beach and Mullaloo Beach, with Pinnaroo Point marking the differentiation between the stable to eroding beaches south of the point, and the stable to accreting beaches north of the point. Most of the remaining coastline between Burns Beach and Mullaloo, and south of Sorrento Beach, consists of stable rocky coastlines with cliffs and wavecut platforms, and small sandy beaches in breaks in the cliff line (Woods, 1984a).

Geomorphology

The study area occurs on two of the three major relict sand dune formations on the Swan Coastal Plain. The majority of the study area consists of the Quindalup Dune system, the youngest of the three systems. The Quindalup Dunes occur as beach ridges, parallel dunes and parabolic dunes. Near Iluka, the Spearwood Dune system occurs adjacent to the coast. The Spearwood Dune system consists of a core of Tamala limestone overlain by yellow sands. The limestone cliffs that occur along the coast in this section of the study area are part of the Tamala limestone formation.

Vegetation

Bush Forever describes the vegetation in terms of four broad structural units, with two units on each of the Spearwood and Quindalup dunes (Government of Western Australia, 2000). The Spearwood Dunes uplands on Tamala limestone in the north of the study area are described as closed to open low heaths dominated by *Melaleuca cardiophylla*, *Melaleuca huegelii*, *Scaevola crassifolia, Spyridium globulosum*, *Dryandra sessilis* var *cygnorum* and *Templetonia retusa.* Mature *Melaleuca systena* ms are prominent in this area. This vegetation type would be vulnerable to degradation following fire. Low shrubland dominated by *Frankenia pauciflora* is present on the cliff-edges in this area, distinguished as a separate vegetation structural unit, occupying a relatively large area south of Burns Beach.

The oldest dunes and plains on the Quindalup Dunes occupy a limited area within the study area and support vegetation that is atypical in such close proximity to the coast, consisting of low heaths to shrublands dominated by *Melaleuca systena* ms, *Acacia rostellifera*, *Acacia xanthina* and *Olearia axillaris*. The strand area closest to the beach supports *Spinifex* grassland, with *S. longifolius* and *S. hirsutus* as well as introduced species such as *Cakile maritima* and *Tetragonia decumbens*.

Bushland Condition and Weeds

A bushland condition survey of the study area was undertaken on the 20th and 21st of November, 2001. The survey utilised the method of Kaesehagen (1995), which includes quantitative elements relating to the percentage cover of weeds and abundance of native species, allowing the survey to repeated at a later date to determine whether weed control works and revegetation programmes have improved the condition of the dunes. Areas of bare sand, erosion and dune blow-outs were also mapped during the survey.

The survey also noted significant populations of priority environmental weeds. The list of priority environmental weeds to be surveyed was drawn from the Environmental Weed Strategy for Western Australia (EWSWA) (CALM, 1999). Common priority weeds in the study area included *Pelargonium capitatum*, *Briza maxima*, *Trachyandra divaricata*, *Euphorbia terracina*, *Avena barbata*, *Bromus diandrus*, *Leptospermum laevigatum*, *Ehrharta calycina*, *Lagurus ovatus*, *Tetragonia decumbens* and *Brassica tournefortii*.

The results of the bushland condition survey as described briefly here, moving from north to south. Most of the coastal vegetation in the **Burns Beach** and **Iluka** area is in *Very Good – Excellent* condition, with small areas of *Fair – Good* and *Poor* condition areas. The northernmost portion of the study area, adjacent to the Burns Beach caravan park, is in *Poor* and *Very Poor* condition due to weed invasion, damage to the structure of vegetation and rubbish dumping. The coastal heath and low woodland vegetation in *Fair* to *Excellent* condition and better is at risk of significant adverse impacts if a fire were to occur. Much of the bushland in the **Ocean Reef** area is also in *Very Good – Excellent* condition, with localised areas of *Fair – Good* and *Poor* condition adjacent to tracks. Much of this area has undergone significant regeneration, with a number of old tracks now no longer visible.

The area of coastal vegetation north of Mullaloo Beach (**North Mullaloo**) retains a core of vegetation in *Very Good – Excellent* condition, again with some areas in poorer condition in areas subject to disturbance. This area has been the subject of intensive revegetation efforts, with some parts of the coastal bushland having been completely cleared until as

recently as ten years ago. The dunes behind the main section of **Mullaloo Beach** vary in condition between *Fair – Good* and *Poor*. Coastal bushland on the high dunes at the northern end of **Whitfords Beach** had a core of vegetation in *Very Good – Excellent* condition, surrounded by bushland in steadily decreasing condition. The bushland adjacent to Northshore Drive has been degraded, with some areas in *Very Poor* condition and other areas having been recently burnt. Weeds were abundant in this area. A number of large dune blow outs were also evident in this area adjacent to the coast. The middle section of Whitfords Beach was generally in *Very Good – Excellent* and *Fair – Good* condition. Further south, near the main areas of public activity towards **Pinnaroo Point**, condition decreased to mainly *Poor* condition, with a higher incidence of grassy weed invasion within the dunes. Some areas of dune erosion were evident along the beach front in this area.

South of Pinnaroo Point, in the **Hillarys Beach** area, the dune vegetation forms a patchwork of areas in varying condition. Although much of the coastal strip of vegetation behind Hillarys Beach is relatively narrow compared to areas further north, significant areas of the strand and foredune areas retain vegetation in *Very Good – Excellent* and *Fair – Good* condition. There was a notable increase in condition values in areas where fences have been constructed in front of the dunes. The dune vegetation behind **Sorrento Beach** forms the narrowest part of the study area. The strand in this area is often in *Fair – Good* condition due to the retention of *Spinifex* species. The remainder of the dune vegetation is generally in *Poor* or *Very Poor* condition due to the impact of past disturbances. Some sections of the dunes in the middle section of **Marmion Beach** are in *Fair – Good* condition or better. Further south, weed invasion has been significant, and a large eroded area is present.

Fauna

No specific surveys of the fauna of the study area are known to have been undertaken (Government of Western Australia, 2000). A large variety of birds nest, breed and feed in the dunes along West Coast Highway, but there are no known endangered species or habitats (Woods, 1984a). The coastal areas are probably also important as habitat for reptiles.

Conservation Values

Most of the study area falls with *Bush Forever* site 325 (Coastal strip from Burns Beach to Hillarys), which extends from north of Hillarys Boat Harbour to the northern limit of the study area. The northern section of the study area, from Burns Beach to north of Mullaloo Beach was also recommended as a conservation reserve in the System 6 report (Department of Conservation and Environment, 1983), as part of M2, which extended north to Two Rocks Open Space. Marmion Marine Park, an A Class Reserve, was established between Trigg Island and Burns Beach in 1987, Western Australia's first Marine Park. The study area also has important linkage value, with adjacent bushland to the east in some areas, and as part of a regionally significant fragmented bushland/wetland linkage (Government of Western Australia, 2000). The study area is part of Greenways 1, 4 and 10 in *A Strategic Plan for Perth's Greenways* (Alan Tingay and Associates, 1998). Although the study area is of high local and regional significance, no values of national or international significance have been identified.

Cultural Heritage

A search of the register of Aboriginal sites one site on the Permanent Register of Aboriginal Sites. This site was an artefact site located in the northern section of the "Pinnacles" in North Mullaloo. A number of historic sites of European heritage have been identified within the study area. A plaque in Geneff Park, near Sorrento and Marmion Beach, commemorates the whaling station established at Marmion in 1849. A number of historic water holes and a spring are located either within or adjacent to the study area. The Gumboya and Whitfords water holes were located to the east of West Coast Highway, outside the study area. Burns Spring was located south of Burns Beach Road, and probably lies within the northern portion of the study area (Woods, 1984b).

Recreation

The dunes, beaches and marine areas of the Joondalup foreshore are used for a number of recreational pursuits, including walking, jogging, cycling, skating, animal exercising, swimming, surfing, diving, waterskiing, sailing, windsurfing, fishing and boating. A dual-use path has recently been finished that traverses almost the entire length (minus 100 metres) of the 14 km of coastal foreshore within the City of Joondalup. Much of the length of the dual use path is fenced on at least one side. This path is well used by pedestrians and cyclists. Designated parks with facilities such as substantial carparks, play equipment, barbeques, toilets, tables and chairs are located at a number of nodes along the foreshore. Popular swimming beaches with large carparks, kiosks, shower blocks, infrastructure and surf lifesaving clubs are located at Mullaloo, Sorrento, Whitfords and Hillarys marina.

Existing Maintenance Framework

Maintenance of the foreshore is currently undertaken by the City of Joondalup's Operations Services however there is no designated single work section that is totally responsible for control and management. Activities carried out include weed control, dune restoration, fencing and maintenance of paths and signage. The existing maintenance framework for the City of Joondalup was investigated, and compared with activities in other nearby coastal local government authorities, including the City of Stirling, City of Wanneroo and Town of Cambridge. Further details can be found in the main body of the report.

Best Practice Management

Best Management Practices for dunes rehabilitation, weed control, fire management and other management issues in coastal areas were reviewed as part of this project. The outcomes of this review were used to inform the plan for management for coastal areas.

Management Zones

Four management zones have been determined for the vegetation of the coastal foreshore of the City of Joondalup in order to guide management and maintenance priorities:

- Conservation;
- Low Intensity Recreation;
- Medium Intensity Recreation; and
- High Intensity Recreation.

Areas proposed for conservation were determined based on the ecological and landform values of the area, independently of the level of public use or land uses present. The three recreation zones were determined based on the existing levels of public use and facilities

present, and the sustainability of each level of use relative to the landform and ecology of each area. All of the conservation areas fall within the low public use zone. Low intensity passive recreation, if properly managed, is deemed to be compatible with meeting the requirement for preservation of areas with high conservation value. As such, the low intensity passive recreation zone overlaps with the conservation zone. Objectives for managing each of the zones were developed.

Recommendations for Management

Dune Restoration

1. Dune rehabilitation should be carried out first in areas of bare sand, erosion and blowouts within the conservation zone. These areas have been mapped as priority rehabilitation zones.
2. Dune rehabilitation and restoration should be carried out in conjunction with a systematic weed control programme.
3. Sand trapping fences, or the lower cost alternative of brush layering, may be appropriate for rebuilding dune blowouts in the Whitfords Beach area, as this section of the coastline is accreting. Placing fences or brush across dune blowouts would at least reduce further human access to these areas. Planning and placement of these structures should occur in the near future, in order to prevent the blow outs from increasing in size.
4. The use of tritter, which consists of guillotined brush (which lies flatter and interlocks more than ordinary brush) should be trialed in rehabilitation in areas exposed to high winds or sandblasting.
5. Aside from areas where dune rehabilitation is of high priority (see Recommendation 1), priorities for dune restoration, weed control and planting programmes should be set according to the bushland condition maps. In general, seeding, planting and brush or mulching will not be required in areas of *Very Good – Excellent* condition. Restoration efforts should commence in areas of *Fair – Good* condition within green areas, with the aim of improving the condition of these areas to *Very Good – Excellent* in the long term. Efforts should move next to areas of *Fair – Good* condition bordering green areas, then to *Poor* areas within *Fair – Good* or *Very Good – Excellent* condition, then to *Poor* areas bordering *Fair – Good* or *Very Good – Excellent* condition, and finally to other *Poor* areas.
6. Given the dynamic nature of coastal areas, and the high potential for further damage to *Poor* and *Very Poor* condition areas, action should be taken as soon as possible to prevent further deterioration of these areas, and to prevent human access. This could involve erection of fences where these are not already present, or placement of temporary stabilisers such as brush, mulch and tritter on exposed surfaces.
7. Species used for dune planting should all be native species local to the area being replanted.
8. Avenues for further involvement of community volunteers in dune replanting should be explored. Community volunteers could be involved in planting of native species, and in seed and propagule collection of parent material. Consideration could be given to establishing a nursery or herbarium in which plants and seeds can be germinated and stored, providing a valuable resource and focus for community activities. Community volunteers could be involved in this process, given proper training and guidance.

9. All areas where restoration has been undertaken should be fenced to prevent human access into the area. In many instances, coastal vegetation can regenerate successfully by reducing disturbance, through fencing and other management techniques.

10. The area of coastal heath adjacent to the extension to Ocean Reef Drive should be fenced before road construction commences.

Weed Control

11. Weed control activities should be guided by the management zones, and by bushland condition and weed mapping. Weed control in conservation zones is considered to be of higher priority than weed control in areas that are not part of the conservation zones. Future weed control efforts should concentrate first on areas of the dunes that are already in relatively good condition, so that the condition of these areas can be improved before tackling more difficult areas[1]. Weed populations in *Very Poor* condition areas are generally not suitable for targeted weed control efforts, and should be controlled as part of a comprehensive rehabilitation plan.

12. Weed control should be undertaken in conjunction with assisted natural regeneration or other dune revegetation techniques such as seeding, planting and mulching.

13. Consideration should be given to provision of training to community volunteers in dune regeneration techniques so that they can contribute to effective weed control, particularly through hand weeding and other non-chemical methods.

14. Each weed control site should be assessed according to which weed species are present, the time of year and available resources. In general, *High* priority weeds[2] should be tackled first, followed by *Moderate* priority weeds. Weed species that were not included in the list of priority species should not be excluded from control activities on that basis. These species should be included in any weed control programme as species which could be controlled if resources allow, but which are not of as high a priority for control.

15. Weed control will continue to be implemented along tracks and pathways due to concerns over fuel loading in the event of a fire. Concerns over the death of native plants due to unintentional spraying of herbicide could be allayed by ensuring more selective application of herbicide.

16. Weed control on coastal dunes where priority weeds are a dominant component of the flora requires careful management to prevent dune erosion and blowouts. *Moderate* rated weeds should only be controlled where there is no danger of erosion. *High* rated weeds should be controlled as appropriate, using herbicide so that the dead plant material remains to bind soil.

17. Native ground-stabilising species should be planted as soon as possible following weed control. Temporary erosion control measures such as placement of tritter, brush and mulch will be necessary until native plants have grown to a sufficient size.

[1] A detailed guide for prioritising weed control works is provided in Section 6.3.2 of the document.

[2] Weeds were prioritised according to the ratings in *Environmental Weed Strategy for Western Australia* (CALM, 1999).

18. Consideration should be given to establishing weed monitoring quadrats in areas subject to weed control to assess the effectiveness of control methods, and any new weed species will be recorded and incorporated into the weed control programme as appropriate. If the city's resources can not be used for this task, it could be a useful educational exercise for school, TAFE or university groups.

Fire Management

19. A Fire Management Plan should be created for the coastal foreshore area that details specific strategies to minimise the risk of wildfire and enable an effective response in the event of a wildfire outbreak. The highest priority area for creating a fire management plan is the coastal heath next to the suburb of Iluka.

20. An adequate east-west aligned firebreak should be constructed in the coastal heath area adjacent to the suburb of Iluka. The construction of this should follow existing tracks where possible to minimise damage caused through construction.

21. In areas where there is a high risk of fire, consideration could be given to creating a low fuel zone on the fenced dune. This could involve removing all weeds and native vegetation from a 20-30 cm band on the fenced side of the dune, treating the area to remove as much weed reproductive matter as possible, and covering the area liberally with mulch, or other low-fuel materials such as succulent ground covers like *Carpobrotus virescens*. This approach would need to be carefully done in conjunction with planting and weed removal along the "edge" of the low fuel zone. This approach could be trialled experimentally along short stretches of the fencing.

22. Rehabilitation should be undertaken as soon as possible in recently burnt areas. Access should be restricted to management purposes only for at least the first six months following the burn by placement of temporary or permanent fencing and/or signage around burnt areas.

23. Consideration should be given to commencing a public education programme on fire in coastal areas, which could include a "Fire Watch" programme, and installation of signage on the effects of fire in areas at high risk of ignition.

Disease Management

24. Movement of soil and plant material from one area to another should be avoided to minimise the possibility of spreading pathogens. Plant material or soil adhering to equipment should be removed before using the equipment in other areas.

25. The naturally occurring Honey Fungus (*Armillaria luteobalbina*) can not be treated. Affected areas will recover, although individual plants will not. The best way to prevent the introduction of *Armillaria* is to minimise stress and disturbance to plants. For seedlings, this may include the use of treeguards, mulch, weed control, reticulation, soil preparation and brushing.

Feral Animals

26. Rabbit control should be undertaken in coastal heath in the Burns Beach/Iluka area, and in all areas of rehabilitation and revegetation. Currently, rabbit control is limited to Pindone baits and rabbit-proof fencing surrounding areas where rabbits have been removed. The use of Pindone baits may not be appropriate, particularly considering

non-target native fauna may also be affected. If rabbit infestation is high, mesh or wire tree-guards may be necessary.

Access and Recreation

27. As resources allow, all conservation zones should be fenced.
28. Recreational use of natural areas should be confined to beach areas, paths, lookouts and designated zones.
29. Pedestrian traffic across sand dunes, in blow outs and on limestone cliffs should be minimised by fencing these areas, with accompanying signage to encourage people to use the paths to improve the condition of coastal areas.

Cost Estimates for Rehabilitation

Cost estimates for the required rehabilitation of the Joondalup coastal foreshore were derived, based on standard rates per square metre for labour, plants, weed control, mulching, brushing and other resources. The coast was divided into sectors, according to areas that have similar management priorities, physical characteristics, and recreational use. The cost for rehabilitation of each of the bushland condition categories, as well as eroded areas and blow-outs, was then calculated for each sector, over a total period of five years.

The following cost estimate is based on the *ideal* scenario in which enough labour, money and resources were available to target all of the Joondalup foreshore within a five year timeframe. The costs below would more likely be spread over greater than five years, for example by staggering the years of establishment for each sector, or by staggering the establishment for certain areas within each sector (ie, for Pinnaroo Point as an example, starting rehabilitation of *Poor* areas in 2002/2003, followed by *Very Poor* areas in 2003/2004 and so on). The costs have been broken down in detail so that if only a limited amount is available for restoration efforts in a given financial year, managers can determine which areas within each sector can realistically be targeted.

The sectors with highest priority for rehabilitation are Iluka Foreshore, North Mullaloo and Whitfords Beach. These areas are all primarily Conservation Zone, with Priority Rehabilitation areas. Priority Rehabilitation areas generally consist of all of the *Poor*, *Very Poor* and *Eroded/Blowout* areas within each of these sectors. On an overall "per hectare" basis, these three sectors have the lowest cost per hectare (between $19,612 and $27,941), as they are in the best condition. Delaying the implementation of rehabilitation would result in increased "per hectare" rehabilitation costs as the condition of degraded areas worsens. For comparison, the average cost of rehabilitation in the degraded Pinnaroo Point sector is $56,900 per hectare, with the highest cost seen as Sorrento Beach, at $90,660 per hectare.

Iluka Foreshore *Area: 41.00 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	**Cost Per Year**
Establishment	$0.00	$0.00	$274,495.00	$41,022.00	$54,696.00	$370,213.00
After 1st Year	$26,235.20	$41,058.00	$109,798.00	$20,511.00	$20,511.00	$218,113.20
After 2nd Year	$26,235.20	$8,211.60	$54,899.00	$8,204.40	$8,204.40	$105,754.60
After 3rd Year	$26,235.20	$8,211.60	$27,449.50	$3,418.50	$3,418.50	$68,733.30
Years thereafter	$26,235.20	$8,211.60	$5,489.90	$683.70	$683.70	$41,304.10
					Total Cost over Five Years	**$804,118.20**

Ocean Reef *Area: 18.76 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$212,245.00	$45,240.00	$0.00	$257,485.00
After 1st Year	$7,724.50	$30,192.00	$84,898.00	$22,620.00	$0.00	$145,434.50
After 2nd Year	$7,724.50	$6,038.40	$42,449.00	$9,048.00	$0.00	$65,259.90
After 3rd Year	$7,724.50	$6,038.40	$21,224.50	$3,770.00	$0.00	$38,757.40
Years thereafter	$7,724.50	$6,038.40	$4,244.90	$754.00	$0.00	$18,761.80
					Total Cost over Five Years	**$525,698.60**

North Mullaloo *Area: 34.35 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment*	$0.00	$0.00	$109,185.00	$94,722.00	$288,328.00	$492,235.00
After 1st Year	$18,951.70	$40,136.00	$43,674.00	$47,361.00	$108,123.00	$258,245.70
After 2nd Year	$18,951.70	$8,027.20	$21,837.00	$18,944.40	$43,249.20	$111,009.50
After 3rd Year	$18,951.70	$8,027.20	$10,918.50	$7,893.50	$18,020.50	$63,811.40
Years thereafter	$18,951.70	$8,027.20	$2,183.70	$1,578.70	$3,604.10	$34,345.40
					Total Cost over Five Years*	**$959,647.00***

In the North Mullaloo Sector, significant efforts have already been put into rehabilitation of degraded areas, particularly areas mapped as "erosion and blowouts". For this reason, the estimated cost of Establishment for eroded areas can be subtracted from the total cost of Establishment, resulting in a total estimated cost of $203,907.00 in the first year of rehabilitation, and a total estimated cost over five years of $671,319.00.

Mullaloo *Area: 12.05 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$164,965.00	$60,408.00	$0.00	$225,373.00
After 1st Year	$1,498.50	$31,208.00	$65,986.00	$30,204.00	$0.00	$128,896.50
After 2nd Year	$1,498.50	$6,241.60	$32,993.00	$12,081.60	$0.00	$52,814.70
After 3rd Year	$1,498.50	$6,241.60	$16,496.50	$5,034.00	$0.00	$29,270.60
Years thereafter	$1,498.50	$6,241.60	$3,299.30	$1,006.80	$0.00	$12,046.20
					Total Cost over Five Years	**$448,401.00**

Whitfords *Area: 20.26 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$136,760.00	$7,122.00	$36,224.00	$180,106.00
After 1st Year	$8,980.10	$39,842.50	$54,704.00	$3,561.00	$13,584.00	$120,671.60
After 2nd Year	$8,980.10	$7,968.50	$27,352.00	$1,424.40	$5,433.60	$51,158.60
After 3rd Year	$8,980.10	$7,968.50	$13,676.00	$593.50	$2,264.00	$33,482.10
Years thereafter	$8,980.10	$7,968.50	$2,735.20	$118.70	$452.80	$20,255.30
					Total Cost over Five Years	**$405,673.60**

Pinnaroo Point *Area: 25.79 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$663,975.00	$114,258.00	$27,904.00	$806,137.00
After 1st Year	$1,751.30	$42,523.00	$265,590.00	$57,129.00	$10,464.00	$377,457.30
After 2nd Year	$1,751.30	$8,504.60	$132,795.00	$22,851.60	$4,185.60	$170,088.10
After 3rd Year	$1,751.30	$8,504.60	$66,397.50	$9,521.50	$1,744.00	$87,918.90
Years thereafter	$1,751.30	$8,504.60	$13,279.50	$1,904.30	$348.80	$25,788.50
					Total Cost over Five Years	**$1,467,389.80**

Hillarys Beach *Area: 12.21 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$116,160.00	$40,278.00	$54,272.00	$210,710.00
After 1st Year	$6,252.00	$11,441.50	$46,464.00	$20,139.00	$20,352.00	$104,648.50
After 2nd Year	$6,252.00	$2,288.30	$23,232.00	$8,055.60	$8,140.80	$47,968.70
After 3rd Year	$6,252.00	$2,288.30	$11,616.00	$3,356.50	$3,392.00	$26,904.80
Years thereafter	$6,252.00	$2,288.30	$2,323.20	$671.30	$678.40	$12,213.20
					Total Cost over Five Years	**$402,445.20**

Sorrento Beach *Area: 4.9 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$200,955.00	$42,270.00	$13,960.00	$257,185.00
After 1st Year	$0.00	$0.00	$80,382.00	$21,135.00	$5,235.00	$106,752.00
After 2nd Year	$0.00	$0.00	$40,191.00	$8,454.00	$2,094.00	$50,739.00
After 3rd Year	$0.00	$0.00	$20,095.50	$3,522.50	$872.50	$24,490.50
Years thereafter	$0.00	$0.00	$4,019.10	$704.50	$174.50	$4,898.10
					Total Cost over Five Years	**$444,064.60**

Marmion Beach *Area: 3.92 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$55,905.00	$34,758.00	$18,472.00	$109,135.00
After 1st Year	$334.40	$8,294.50	$22,362.00	$17,379.00	$6,927.00	$55,296.90
After 2nd Year	$334.40	$1,658.90	$11,181.00	$6,951.60	$2,770.80	$22,896.70
After 3rd Year	$334.40	$1,658.90	$5,590.50	$2,896.50	$1,154.50	$11,634.80
Years thereafter	$334.40	$1,658.90	$1,118.10	$579.30	$230.90	$3,921.60
					Total Cost over Five Years	**$202,885.00**
Total Cost over Five Years with Professional Labour						**$5,660,323.00**
Total Cost minus cost of Establishment for eroded areas in North Mullaloo						$5,371,995.00

The costs shown above are high in relation to the current expenditure on management of coastal and bushland areas in the City of Joondalup. The use of volunteer labour may cut the figure down by about half, but even this would still be far higher than current expenditure. However, in order to maintain the current excellent condition of much of the foreshore, and to improve the condition of degraded areas, an increase in expenditure is needed. Further, expenditure in the present will minimise future expenditure on degraded areas. The City of Joondalup's coastal foreshore is an important asset, with high conservation values, that is valued by residents and visitors alike, and further funding should be sourced to allow for maintenance of these values.

1.0 Introduction

Joondalup Coastal Foreshore Natural Areas Management Plan

The City of Joondalup coastal foreshore represents an important regional resource that requires appropriate management in order to sustain it over time. Most of the 14 km foreshore is recognised as having regional conservation significance in *Bush Forever* (Government of Western Australia, 2000), containing significant areas of coastal limestone cliffs, coastal heathland, landscape values such as high dunes, and acting as a regional green corridor. Increasing pressure on the coastal reserves, due largely to increasing population and recreational demands, if not properly managed, could result in significant changes to the structure and function of the coastal ecosystem, as well as to the aesthetic value and recreation amenity of the area. This report presents the results of a study into the current condition of the coastal vegetation and dunes, and the optimum management and maintenance framework to preserve and enhance the conservation value of the coastal foreshore vegetation.

1.1 Objectives

The overall objective of this study was to:

- Prepare a report and recommendations detailing the optimum control and management practices for the future control and management of the coastal foreshore vegetation of the City of Joondalup.

More specific objectives for the projects were to:

1. Review existing literature and management plans encompassing the study area, and other regions with similar coastal conditions;
2. Identify the priorities for preservation of the coastal foreshore vegetation as a community asset by assessing conservation value, vegetation condition, and priority areas for rehabilitation;
3. Assess the current relative levels of public access and use of the foreshore area;
4. Set a spatial framework for management and maintenance by identifying zones for conservation, and high, medium and low recreational public use;
5. Identify the optimum coastal maintenance and management practices, by reviewing existing planning and management mechanisms throughout the local area and other parts of Australia, and evaluating the success, costs and benefits of current maintenance practices;
6. Develop recommendations for management and maintenance specific to each management zone in order to attain sustainable use of the coastal area, whilst preserving and enhancing conservation values; and
7. Develop an implementation plan for the future management of the foreshore, with priorities for each set of recommendations, and an indication of the likely cost of each strategy.

1.2 Location

The extent of the study area are shown in Figures 1a and 1b. Figure 1b, supplied by the City of Joondalup, shows aerial photography of the study area, while Figure 1a shows location names. The study area included all areas of vegetation within the coastal foreshore area managed by the City of Joondalup. The waste water treatment area in Ocean Reef, the Whitfords Nodes area and Hillarys Boat Harbour were all excluded from the study area. For consistency, the various sections of coast within the study area have been referred to into sections according to (largely) commonly used names, including (from north to south):

- Burns Beach;
- Iluka Foreshore (the nodal recreational area in Iluka);
- Ocean Reef (the area near the boat harbour);
- "North Mullaloo", between the more commonly accessed Mullaloo Beach and Ocean Reef;
- The "Little Desert" or "Pinnacles" in the Mullaloo area;
- Mullaloo Beach;
- Whitfords Beach, extending from the Pinnaroo Point to Mullaloo Beach;
- Pinnaroo Point;
- Hillarys Beach, from Pinnaroo Point to Hillarys Boat Harbour;
- Whitfords Nodes, the recreational and dune conservation area behind Hillarys Beach;
- Sorrento Beach; and
- Marmion Beach.

1.3 Tenure, Vesting and Zoning

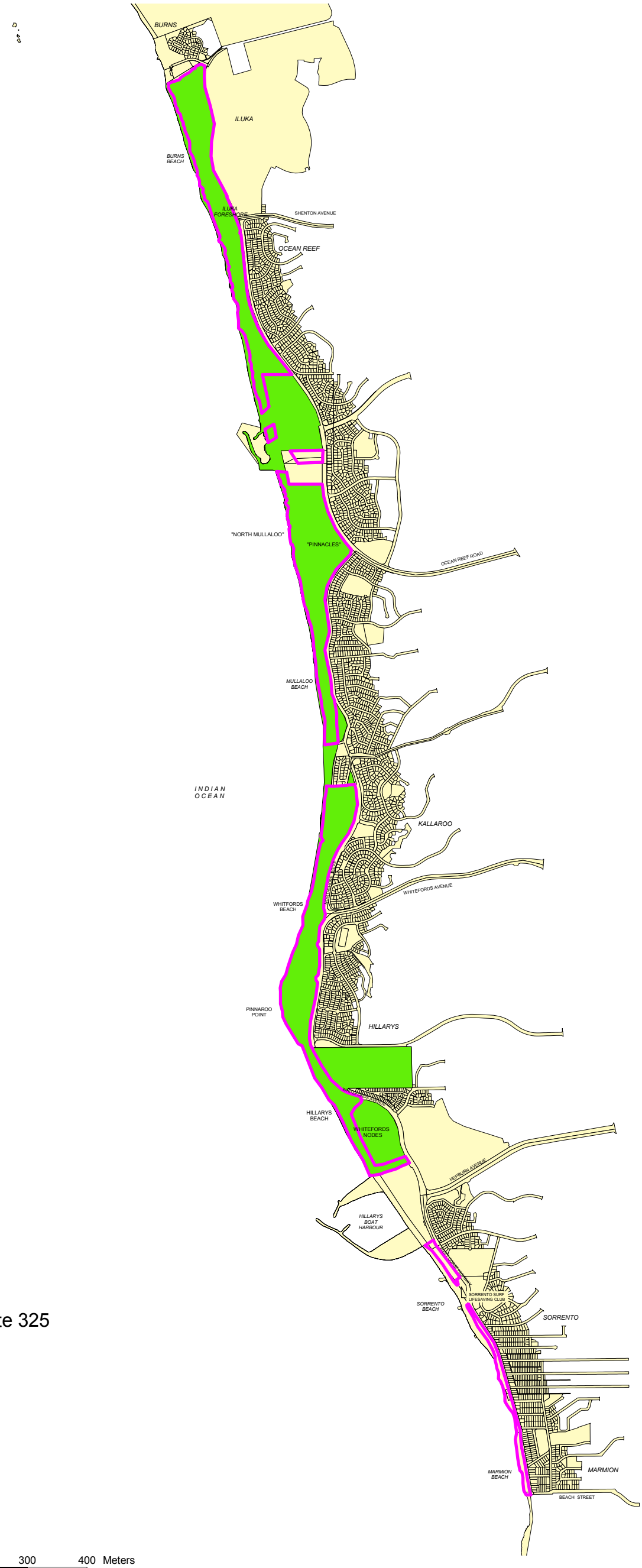
The Department of Land Administration has listed 31 reserves in the Joondalup foreshore area, of which 17 are greater than 1 ha. However, not all of these reserves are within the study area. The City of Joondalup's Lands Office is currently preparing a map showing the lot and location numbers for reserves in the City of Joondalup, which should be complete by mid-May. Once the map has been finished, it will be possible to determine the areas that are including in the study, and the vesting and tenure of these areas will be available. This information will be available in the final report.

1.3.1 Zoning

The local zoning of the study area is mostly Parks and Recreation, with the MRS zoning as Regional Reserve – Parks and Recreation. According to data from the City of Joondalup, there may be small areas of Public Purposes – Special Uses within the foreshore area, but this will be clarified once mapping of the reserves is complete in mid-May.

1.3.2 Area

GIS enquiry by the City of Joondalup showed that the foreshore area included in the study was 239 ha. However, the summary of the areas of bushland condition mapped by Ecoscape showed that the total area surveyed for this report was approximately 173 ha. The bushland condition maps do not include areas of beach sand, carparks and grassed areas, which probably accounts for the difference between these figures.



LEGEND

- Study area
- Bush Forever site 325
- Cadastre

N

100 0 100 200 300 400 Meters

• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL CONSULTANTS
9 Stirling Highway North Fremantle Western Australia 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

FIGURE 1(a): Study Area and Bush Forever Sites

Figure 1b: Aerial photography of the study area

2.0 Biophysical Environment and Conservation Values

Joondalup Coastal Foreshore Natural Areas Management Plan

2.1 Geomorphology

The study area occurs on two of the three major relict sand dune formations on the Swan Coastal Plain. The majority of the study area consists of the Quindalup Dune system, the youngest of the three systems. The Quindalup Dunes are composed of calcareous sands known as the Safety Bay Sands, which are generally well sorted and comprised of white, medium grained, rounded quartz and shell debris. The Quindalup Dunes occur as beach ridges, parallel dunes and parabolic dunes (Churchward and McArthur, 1980).

Near Iluka, the Spearwood Dune system occurs adjacent to the coast. The Spearwood Dune system consists of a core of Tamala limestone overlain by yellow sands. Within the study area, the landform has been subject to high wind erosion, resulting in the Cottesloe formation, which consists of shallow yellow-brown sand and exposed limestone. The limestone cliffs that occur along the coast in this section of the study area are part of the Tamala limestone formation.

The skeleton of the Joondalup coastal zone comprises four to five parallel limestone ridges, the two largest lying to the east. The western ridge forms the mainland coast, with a chain of islands and reefs offshore (Woods, 1984a). Superimposed on this limestone basement are a number of landforms associated with the younger sandy deposits. These include submarine banks, transgressive dunes, beach ridges, beach ridge plains, marine basins, wave cut platforms and cliffs, and beaches.

The coastline within the study area continues to undergo change related to long-term changes in sea level. Sand is still being supplied to the coast, offshore reefs are undergoing erosion, and the shape of sandy parts of the coast continue to change in response to changes in sand supply and wave direction (Woods, 1984b). The coastal formations of the study area can be divided into three broad types, with one type further divisible into two sub-types. These are:

- Sandy coasts around beach ridge plains (the Whitfords Plain, for example), that project beyond the general trend of the coast. These coasts can then be further divided into south facing flanks (Type A in Figures 2 and 3) and north facing flanks (Type B);
- An eroding or stable sandy coast cut into the seaward margin of the younger dunes that overlie the limestone basement (Type C) ; and
- A stable rocky coast fronted by a limestone cliff and wave cut platform, such as at south of Sorrento and north of Mullaloo (Type D) (Woods, 1984b).

All four of these coastal formations occur within the study area, with implications for management of these zones. Figure 2 shows the position of these formations in relation to the study area. Typical cross-sections of each of the types are shown in Figure 3. Between Sorrento Beach and Mullaloo Beach coastal processes have led to the formation of sandy

coasts around beach ridge plains, with Pinnaroo Point marking the differentiation between the south-facing flank, south of Pinnaroo Point, and the north-facing flank, north of Pinnaroo Point. The south-facing flank is considered to be stable to eroding, while the north-facing flank is considered to be stable to accreting (Woods, 1984b). Truncated dune fields occur in a section north of Mullaloo Beach, south of the Ocean Reef harbour. This coastal type is considered to be stable to eroding. Along the other coastal areas (north of the section of truncated zones and Mullaloo and south of Sorrento) rocky coastlines occur where the western ridge has been eroded to form cliffs and wavecut platforms with small sandy beaches located in breaks in the cliff line (Woods, 1984a). Rocky coastlines are considered to be stable (Woods, 1984b).

There is a submarine bank, partially covered by the Whitfords Plain, between Sorrento and Mullaloo, which partitions the near-shore depression into two discreet basins. Adjacent to the bank, the western ridge is partially covered by a veneer of transgressive dunes, all of which are stabilised by vegetation with the exception of "Little Desert" or "Pinnacles" in Mullaloo. This active dune is now cut off from the beach by a vegetated foredune. The southern half of the Whitfords Plain is fronted by a narrow beach and steep dune cliff, and covered by stabilised transgressive dunes. The northern half of the plain is lower, and beach ridges which mark successive shoreline positions during growth of the plain are visible.

2.2 Wind and Wave Action

The prevailing direction of the swell is from the south west, consisting of a long period (7 to 15 seconds) swell continually generated in the Southern and Indian Oceans. Short period (2 to 7 seconds) wind waves are superimposed on the swell waves. During summer, south west wind waves are generated by the sea breeze, and in winter high energy wind waves can be generated during north west and westerly gales (Woods, 1984b).

Waves arriving at an angle to the shore generate a longshore current in the surf zone within the study area, especially between Sorrento and Pinnaroo Point, and north of Mullaloo (Woods, 1984b; City of Wanneroo Town Planning Department, 1991b). Sediment is suspended and transported in the surf zone, giving rise to "littoral drift" of sediment along the coast. The direction of the longshore current is generally northwards in summer and southwards during winter, due to changes in the directions of prevailing winds between the seasons (Woods, 1984b). This process has implications for the function and usefulness of constructed coastal structures, such as groynes, where sand will be eroded from the down-current side of the groyne, and deposited on the up-current side. The beach on the northern side of Hillarys marina has suffered beach erosion from this process in the past.

At present, there appears to be little sand transport inland except in areas where human presence has degraded dune vegetation or the dune scarp behind the beach. The presence of transgressive dunes is evidence of previous periods of major wind transport. The coast between Sorrento and Pinnaroo Point appears to be in a state of long term erosion, indicated by the lack of a foredune in some areas. The beaches north of Pinnaroo Point are in a state of long-term accretion, despite the presence of a small erosion scarp along the front of the beach ridges (Woods, 1984a). A typical beach sand cycle is apparent on most sandy beaches in the area, where winter storms move sand from the beach to an offshore sand bar, and summer swell patterns re-deposit it on the beach (City of Wanneroo Town Planning Department, 1991a).

Figure 2: Types of coastal formations along the Joondalup Coast, Marmion Beach to Burns Beach.

The coastline is shown in orange. The letters in each of the segments refer to the four coastal types, detailed in the text and in Figure 3. Source: Woods (1984b), Map 1.

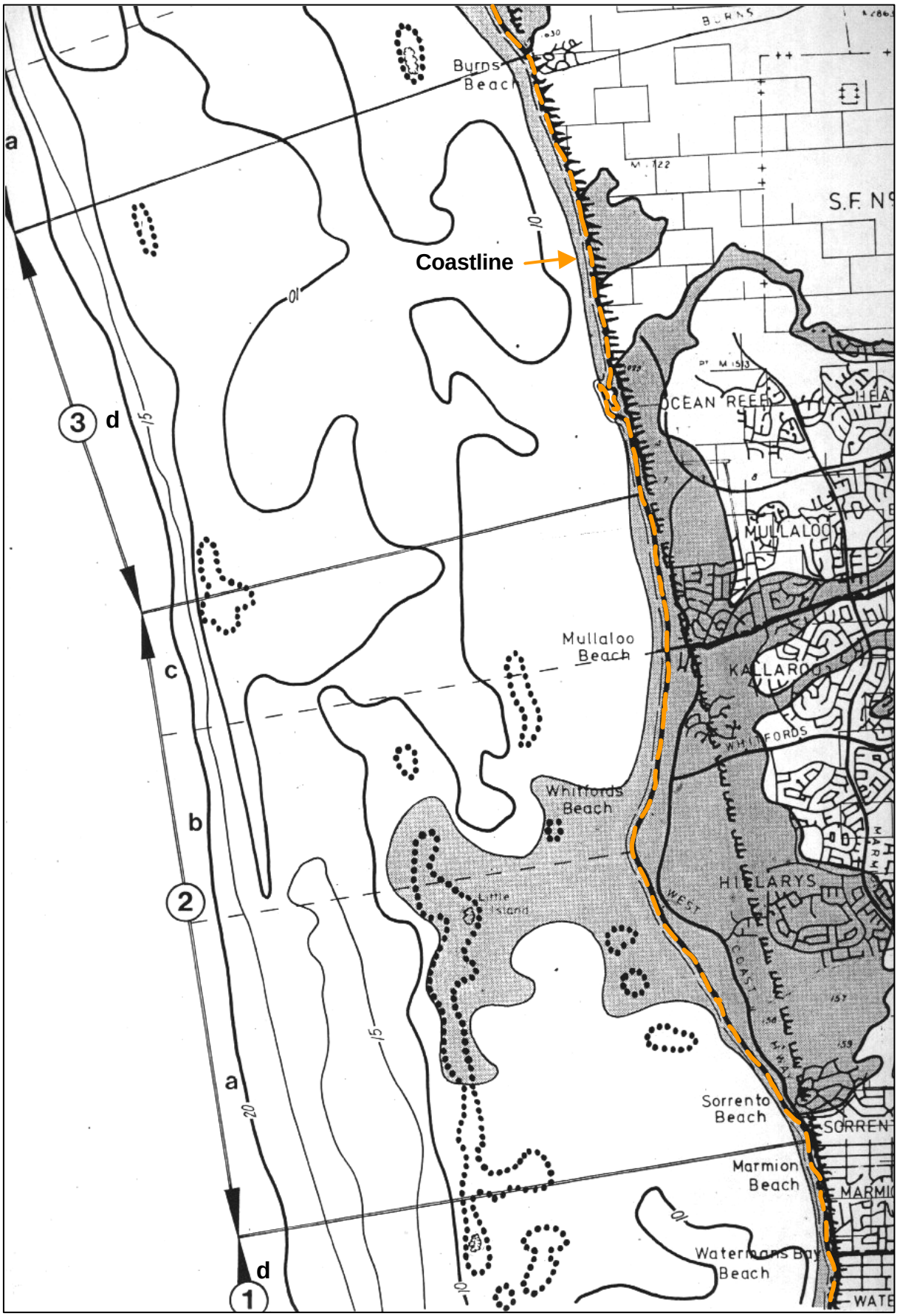
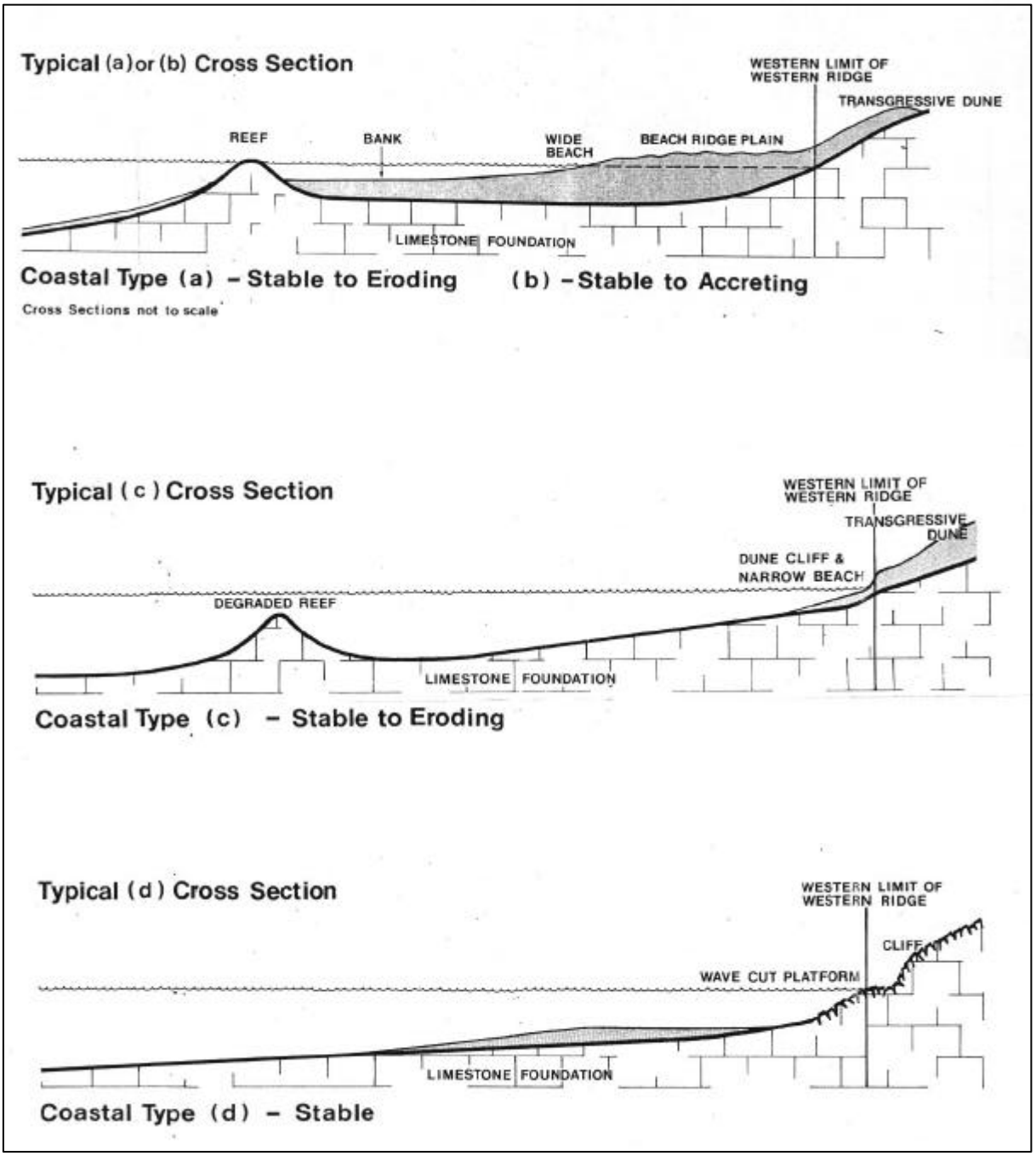


Figure 3: Cross sectional diagrams of the four types (a, b, c and d) of coastal formations present along the Joondalup coast.

Source: Woods (1984b), Map 1.



2.3 Vegetation and Flora

2.3.1 Vegetation Complexes

The study area includes two of the vegetation complexes as described by Heddle *et al*. (1980). These vegetation complexes correspond to major landforms and soil types defined by Churchward and McArthur (1980), and are recognised in *Bush Forever* (Government of Western Australia, 2000). The Quindalup vegetation complex is associated with the Quindalup Dune system, and can be divided into two alliances based on the type of dune: the strand and foredune alliance, and the mobile and stable dune alliance. Both of these alliances occur within the study area. The strand and fore dune alliance includes species such as *Angianthus cunninghamii*, *Atriplex isatidea*, *Cakile maritima*, *Calocephalus brownii*, *Carpobrotus virescens*, *Pelargonium capitatum*, *Senecio lautus*, *Spinifex longifolius*, *Spinifex hirsutus* and *Tetragonia implexicoma*. The mobile and stable sand dune alliance contains *Acacia cyclops*, *Anthocercis littorea*, *Lepidosperma gladiatum*, *Olearia axillaris*, *Myoporum insulare*, *Scaevola crassifolia*, *Spyridium globulosum*, *Westringia rigida* and *Wilsonia backhousei*. Low closed forest of *Melaleuca lanceolata* and *Callitris preissii* is restricted to small localised pockets along the coast, although it was once more widespread. Other local variations include occurrences of *Eucalyptus foecunda*, *Pittosporum phillyraeoides*, *Santalum acuminatum, Exocarpus sparteus* and *Acacia rostellifera* (Heddle *et al*., 1980). Recent mapping indicates that 48% of vegetation complexes associated with Quindalup dunes remain as native vegetation (Government of Western Australia, 2000). However, it is considered that existing conservation reserves do not adequately cover the variety of geomorphic, habitat and vegetation systems in the Quindalup dunes (EPA, 1994).

The Cottesloe – Central and South complex occurs on the Cottesloe formation of the Spearwood Dune system, which occurs in the Iluka portion of the study area. This complex includes closed heath on limestone outcrops. Typical species on limestone outcrops include *Melaleuca huegelii*, *M. cardiophylla*, *Trymalium ledifolium*, *Grevillea thelemanniana*, *G. vestita*, *Jacksonia hakeoides* and *Conospermum triplinervium*. It is considered that this vegetation complex is only moderately well conserved, is best reserved at its extremities and is poorly reserved between Mandurah and Perth (EPA, 1994).

2.3.2 Vegetation Description

A number of vegetation and flora surveys have included parts of the study area (Government of Western Australia, 2000). *Bush Forever* describes the vegetation in terms of four broad structural units, with two units on each of the Spearwood and Quindalup dunes (Government of Western Australia, 2000). The Spearwood Dunes uplands on Tamala limestone in the north of the study area are described as closed to open low heaths dominated by *Melaleuca cardiophylla*, *Melaleuca huegelii*, *Scaevola crassifolia, Spyridium globulosum*, *Dryandra sessilis* var *cygnorum* and *Templetonia retusa.* Mature *Melaleuca systena* ms[1] are prominent in this area. This vegetation type would be vulnerable to degradation following fire, due to the age of many of the shrubs with large volumes of fuel in the form of dead lower branches, the length of time that fire has been excluded, and the presence of large numbers of rabbits that could inhibit post-fire regeneration by grazing seedlings. Low shrubland

[1] *Melaleuca systena* ms was formerly known as *Melaleuca acerosa*.

dominated by *Frankenia pauciflora* is present on the cliff-edges in this area, distinguished as a separate vegetation structural unit, occupying a relatively large area south of Burns Beach.

The oldest dunes and plains on the Quindalup Dunes occupy a limited area within the study area and support vegetation that is atypical in such close proximity to the coast, consisting of low heaths to shrublands dominated by *Melaleuca systena* ms, *Acacia rostellifera*, *Acacia xanthina* and *Olearia axillaris*. The strand area closest to the beach supports *Spinifex* grassland, with *S. longifolius* and *S. hirsutus* as well as introduced species such as *Cakile maritima* and *Tetragonia decumbens*.

2.3.3 Floristic Community Types

A number of floristic community types have been defined for the Swan Coastal Plain region. These floristic community types are based on analysis of detailed floristic data from a large number of quadrats located throughout the region. The floristic community types (as defined by Gibson *et al*., (1994) and subsequent work summarised in *Bush Forever* (Government of Western Australia, 2000)) that have been confirmed or inferred from locations within the study area are:

- Type 16: Highly saline seasonal wetlands (refers to *Frankenia pauciflora* low shrubland on Tamala limestone cliffs);
- Type 27: Species-poor mallees and shrublands on limestone;
- Type 29a: Coastal shrublands on shallow sands;
- Type 29b: Acacia shrublands on taller dunes;
- Type S11: Northern *Acacia rostellifera – Melaleuca systena* ms shrublands;
- Type S13: Northern *Olearia axillaris – Scaevola crassifolia* shrublands; and
- Type S14: *Spinifex longifolius* grasslands and low shrublands.

None of these floristic community types are recognised as threatened ecological communities.

2.3.4 Flora

The flora of the Quindalup dunes is typically less than that of the older, inland dune systems. One survey conducted in the Burns Beach Coastal Reserve area (Keighery and Keighery, 1992) found 38 native taxa and 8 weed taxa, which was thought to be greater than 60% of the total expected flora in the study area.

Significant flora previously recorded from within *Bush Forever* site 325 include *Hibbertia spicata* subsp *leptotheca*, a Priority 3 species[3], the southernmost large population of *Melaleuca cardiophylla*, *Plantago exilis*, which is the only known record of this species in the Perth metropolitan region, *Alyogyne huegelii* var *glabrescens* and *Kennedia coccinea*, both of which are considered significant in the Perth metropolitan region (Government of Western Australia, 2000).

[3] Defined as species which are known from several populations, at least some of which are not believed to be under immediate threat, either due to the number of known populations (generally >5), or known populations being large, and either widespread or protected.

2.4 Bushland Condition and Weed Survey

2.4.1 Method

A bushland condition survey of the study area was undertaken on the 20th and 21st of November, 2001. The survey utilised the method of Kaesehagen (1995), given in Table 1 below. This method includes quantitative elements relating to the percentage cover of weeds and abundance of native species, allowing the survey to repeated at a later date to determine whether weed control works and revegetation programmes have improved the condition of the dunes. The bushland condition survey was mindful of the fact that coastal areas are naturally dynamic and this feature has to be considered in the assessment of their condition. Bare areas and blow-outs are natural features that provide important habitat areas for animals such as burrowing reptiles. Areas of bare sand, erosion and dune blow-outs were also mapped during the survey.

The survey also noted significant populations of priority environmental weeds. The list of priority environmental weeds to be surveyed was drawn from the Environmental Weed Strategy for Western Australia (EWSWA) (CALM, 1999). The EWSWA criteria for determining priority for control were developed after assessing over 1000 weed species in Western Australia, and are as follows:

- Invasiveness – ability to invade bushland in good to excellent condition or ability to invade waterways;
- Distribution – wide current or potential distribution including consideration of known history of widespread distribution elsewhere in the world; and
- Environmental Impacts – ability to change the structure, composition and function of an ecosystem, in particular, an ability to form a monoculture in a vegetation community.

High rated weeds have all three of these characteristics, and *Moderate* rated weeds have any two of these characteristics. Coastal weeds that were rated as *High* or *Moderate* were counted as priority weeds, as well as other weeds that may have only a *Mild* or *Low* rating but can be considered a problem in coastal areas, such as *Trachyandra divaricata*. Weeds present in high abundance that were not priority weeds were also recorded where appropriate. Weeds included on the priority list and their EWSWA priorities for control are given in Table 2.

Table 1: Bushland condition scale

Source: Kaesehagen (1995).

Very Good – Excellent	Fair to Good
• 80 – 100% Native Flora composition • Vegetation structure intact or nearly so • Cover/abundance of weeds less than 5% • Minor signs of disturbance	• 50 – 80% Native Flora composition • Vegetation structure modified or nearly so • Cover/abundance of weeds 5 – 20% • Disturbance influence moderate
Poor	**Very Poor**
• 20 – 50% Native Flora composition • Vegetation structure completely modified • Cover/abundance of weeds 20 – 60% • Disturbance incidence high	• 0 – 20% Native Flora composition • Vegetation structure disappeared • Cover/abundance of weeds 60 – 100% • Disturbance incidence very high

Table 2: Priority environmental weeds targeted during bushland condition and weed surveys.

Taxonomic Name	Common Name	EWSWA[1] Priority Ratings
Anagallis arvensis	Pimpernel	Moderate
Arctotheca calendula	Cape Weed	Moderate
Arctotheca populifolia	Dune Arctotheca	Moderate
Avena barbata	Bearded Oat	Moderate
Briza maxima	Blowfly Grass	Moderate
Briza minor	Shivery Grass	Moderate
Cakile maritima	Sea Rocket	Moderate
Carpobrotus edulis	Pigface	Moderate
Crassula glomerata	Crassula	Moderate
Euphorbia peplus	Petty Spurge	Moderate
Euphorbia terracina	Geraldton Carnation Weed	High
Lagurus ovatus	Hare's Tail Grass	High
Malva dendromorpha	Tree Mallow	High
Leptospermum laevigatum	Victorian Tea Tree	High
Mesembryanthemum crystallinum	Iceplant	Moderate
Oenothera drummondii	Beach Evening Primrose	Moderate
Pelargonium capitatum	Rose Pelargonium	High
Tetragonia decumbens	Sea Spinach	Moderate
Trachyandra divaricata	Strapweed	Mild

2.4.2 Results

The results of the bushland condition and weed survey are shown in Figure 4. Most of the coastal vegetation in the Burns Beach/Iluka area is in *Very Good – Excellent* condition, with small areas of *Fair – Good* and *Poor* condition areas (Plate 1). There is a sizeable area of *Fair – Good* condition heathland where weed cover included *Pelargonium capitatum*, *Bromus diandrus* and *Trachyandra divaricata*. The northernmost portion of the study area, adjacent to the caravan park, is in *Poor* and *Very Poor* condition due to weed invasion, damage to the structure of vegetation and rubbish dumping. Abundant weeds in this area include *Carpobrotus edulis*, *Euphorbia terracina*, *Pelargonium capitatum*, *Avena barbata*, *Bromus diandrus* and *Leptospermum laevigatum*. The coastal heath and low woodland vegetation in *Fair – Good* condition and better is probably at risk of significant adverse impacts if a fire were to occur. A number of small fires have occurred further south in the Burns Beach area, near the grassed recreational areas of the Iluka Foreshore. The extension of Ocean Reef Drive that is due to occur within the next twelve months will require fencing of the coastal foreshore and careful attention to weed control. The coastal heath closest to the cleared road reserve is already showing signs of degradation in some areas, with weed invasion and litter present.

Much of the bushland in the Ocean Reef area is also in *Very Good – Excellent* condition, with localised areas of *Fair – Good* and *Poor* condition adjacent to tracks (Plate 2). Common weeds adjacent to tracks and disturbed areas included *Bromus diandrus*, *Avena barbata*, *Euphorbia terracina*, *Lagurus ovatus*, *Pelargonium capitatum*, *Tetragonia decumbens* and *Ehrharta calycina*. Much of this area has undergone significant regeneration, with a number of old tracks now no longer visible.

Plate 1: Excellent condition bushland in the Iluka Foreshore Sector

The high conservation value of the coastal heath can be seen clearly in this picture. This vegetation would be at great risk in case of fire, due to the maturity of the plants (which would provide large amounts of fuel) and the abundance of rabbits in the area (which would graze on new germinants following fire). Photo: N. Pauli

Plate 2: Bushland along the coast in the Ocean Reef Sector

This picture shows the relatively higher abundance of weeds near the coast, as well as the persistence of some informal tracks to fishing spots on the coastal cliffs. Photo: Kelli O'Neill.

The area of coastal vegetation north of Mullaloo Beach ("North Mullaloo") retains a core of vegetation in *Very Good – Excellent* condition, again with some areas in poorer condition in areas subject to disturbance. This area has been the subject of intensive revegetation efforts, with some parts of the coastal bushland having been completely cleared until as recently as ten years ago. Significant restoration efforts are in place in this area and have been mapped. The dunes behind the main section of Mullaloo Beach vary in condition between *Fair – Good* and *Poor*, with common weeds including *Pelargonium capitatum*, *Tetragonia decumbens*, *Lagurus ovatus* and *Euphorbia terracina*.

Coastal bushland on the high dunes at the northern end of Whitfords Beach shows a distinctive zonation pattern, with a core of vegetation in *Very Good – Excellent* condition, surrounded by bushland in steadily decreasing condition. This effect is typical of the results of "edge effects" where bushland areas are surrounded by cleared land, and are prone to the effects of weed invasion, disturbance and fire around the edges adjacent to cleared areas. The bushland adjacent to Northshore Drive has been particularly severely affected, with some areas in *Very Poor* condition and other areas having been recently burnt. Weeds were abundant in this area, including *Avena barbata*, *Pelargonium capitatum* and *Euphorbia terracina* as the most common species. A number of large dune blow outs were also evident in this area adjacent to the coast, with colonisation by weeds around the margins, including *Trachyandra divaricata*, *Lagurus ovatus* and *Brassica tournefortii*.

The middle section of Whitfords Beach was generally in *Very Good – Excellent* and *Fair – Good* condition. Further south, near the main areas of public activity towards Pinnaroo Point, a notable decrease in condition was evident, with a higher incidence of grassy weed invasion within the dunes. Although much of the vegetation is in *Poor* condition, this area has undergone substantial regeneration of the native vegetation since the area was cleared and used as a location for fishing shacks several decades ago. Some areas of dune erosion were evident along the beach front in this area.

South of Pinnaroo Point, in the Hillary's Beach area, the dune vegetation forms a patchwork of areas in varying condition. Although much of the coastal strip of vegetation behind Hillary's Beach is relatively narrow compared to areas further north, significant areas of the strand and foredune areas retain vegetation in *Very Good – Excellent* and *Fair – Good* condition. The presence of good condition vegetation and absence of erosion along some areas of the foreshore in this area appears to be correlated with the presence of fences adjacent to the strand, with a notable increase in condition values where a fence has been established. Several small patches of dune vegetation have been recently burnt in this section of the study area.

The dune vegetation behind Sorrento Beach forms the narrowest part of the study area. A number of substantial weed control programs have been undertaken on the dunes north of the Sorrento Surf Life Saving Club, with removal of much of the extensive areas of *Pelargonium capitatum*. The strand in this area is often in *Fair – Good* condition due to the retention of *Spinifex* species. The remainder of the dune vegetation is generally in *Poor* or *Very Poor* condition due to the impact of past disturbances. Some sections of the dunes in the middle section of Marmion Beach are in *Fair – Good* condition or better. Further south, weed invasion has been significant, and a large eroded area is present.

2.5 Fauna

No specific surveys of the fauna of the study area are known to have been undertaken (Government of Western Australia, 2000). A large variety of birds nest, breed and feed in the dunes along West Coast Highway, but there are no known endangered species or habitats (Woods, 1984a). The coastal areas are probably also important as habitat for reptiles.

The reefs along the Joondalup coast support a variety of fish, shellfish and crustaceans. A rare cowrie shell inhabits the reefs near Whitfords (Woods, 1984a). The protected deeper marine basins between the reef and the mainland are probably important nursery grounds for fish, shellfish and crayfish (Woods, 1984b). Two species of marine mammals frequent the park: the bottlenose dolphin and Australian sea lion.

FIGURE 4(a): Bushland Condition, Weed Invasion and Dune Erosion

BURNS

BURNS BEACH

BURNS BEACH ROAD

Abundant weeds along track edge including Carpobrotus edulis, Euphorbia terracina, Pelargonium capitatum, Avena barbata, Bromus diandrus, Leptospermum laevigatum

Some Pelargonium caitatum, Bromus diandrus, Trachyandra divaricata

INDIAN OCEAN

ILUKA

On west side of track, full vegetation cover of dunes, although Pelargonium capitatum to 40% and Tetragonia decumbens to 10%

SHENTON AVENUE

Iluka Foreshore Sector

OCEAN REEF

OCEAN REEF ROAD

Ocean Reef Sector

LEGEND

BUSHLAND CONDITION SCALE

Very Good - Excellent
80 -100% Native Flora composition
Cover/abundance of weeds less than 5%
Minor signs of disturbance

Fair - Good
50-80% Native Flora composition
Vegetation structure modified or nearly so.
Disturbance influence moderate.
Cover/abundance of weeds 5-20%

Poor
20-50% Native Flora composition.
Vegetation structure completely modified.
Disturbance incidence high.
Cover/abundance of weeds 20-60%

Very Poor
0-20% Native Flora composition.
Vegetation structure disappeared.
Disturbance incidence very high.
Cover/abundance of weeds 60-100% cover

Recently Burnt

DUNE BLOWOUT / EROSION

REHABILITATION ZONE

CADASTRE

TRACKS

SECTOR BOUNDARY

MAP SHEET LAYOUT

4(a)
4(b)
4(c)
4(d)
4(e)
4(f)

N

100 0 100 200 300 400 Meters

• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL CONSULTANTS
9 Stirling Highway North Fremantle Western Australia 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

JOINS FIGURE 4(b)

FIGURE 4(e): Bushland Condition, Weed Invasion and Dune Erosion

JOINS FIGURE 4(d)

WHITFORDS AVENUE

Recently burnt areas have a high proportion of grassy weeds.

Around 80% weeds - Avena barbata, Ehrharta calycina, Euphorbia terracina, Bromus diandrus.

Hillarys Beach Sector

INDIAN OCEAN

Tetragonia decumbens, Avena barbata, Trachyandra divaricata, Pelargonium capitatum, together about 20% cover.

Avena barbata to 60%, Bromus diandrus to 15%, Lagurus ovatus to 15%.

HEPBURN AVENUE

HILLARYS BOAT HARBOUR

WEST COAST HIGHWAY

Tetragonia decumbens to 70%

SORRENTO BEACH

Sorrento Beach Sector

JOINS FIGURE 4(f)

LEGEND

BUSHLAND CONDITION SCALE

Very Good - Excellent
80 -100% Native Flora composition
Cover/abundance of weeds less than 5%
Minor signs of disturbance

Fair - Good
50-80% Native Flora composition
Vegetation structure modified or nearly so.
Disturbance influence moderate.
Cover/abundance of weeds 5-20%

Poor
20-50% Native Flora composition.
Vegetation structure completely modified.
Disturbance incidence high.
Cover/abundance of weeds 20-60%

Very Poor
0-20% Native Flora composition.
Vegetation structure disappeared.
Disturbance incidence very high.
Cover/abundance of weeds 60-100% cover

Recently Burnt

DUNE BLOWOUT / EROSION

REHABILITATION ZONE

CADASTRE

TRACKS

SECTOR BOUNDARY

MAP SHEET LAYOUT

4(a)
4(b)
4(c)
4(d)
4(e)
4(f)

N

100 0 100 200 300 400 Meters

• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL CONSULTANTS
9 Stirling Highway North Fremantle Western Australia 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

JOINS FIGURE 4(c)

FIGURE 4(d): Bushland Condition, Weed Invasion and Dune Erosion

Weeds up to 80%, including Lagurus ovatus, Trachyandra divaricata, Bromus diandra.

Abundant weeds along track, including Avena barbata up to 80% Pelargonium capitatum and Euphorbia terracina.

Around blowout :
Trachyandra divaricata up to 80%,
Lagurus ovatus up to 30%,
Brassica tournefortii up to 20%

INDIAN OCEAN

KALLAROO

MAP SHEET LAYOUT

4(a)
4(b)
4(c)
4(d)
4(e)
4(f)

Whitfords Beach Sector

Lagurus ovatus common in this area.

NORTHSHORE DRIVE

WHITFORDS AVENUE

WHITFORDS BEACH

Nearly 100% weeds, including Arctocis populifolia, Avena barbata, Trachyandra divaricata and Euphorbia poplus.

Pinnaroo Point Sector

Castor oil plants.

Regenerating vegetation, with weeds including Euphorbia terracina, Bromus diandrus, Lagurus ovatus, Ehrharta calycina and Avena barbata

100% weeds including Euphorbia terracina Tetragonia decumbens, Oenothera drummondii.

Tetragonia decumbens to 70% on foredunes.

Abundant grassy weeds behind foredune including Bromus diandrus, Lagurus ovatus, Avena barbata.

PINNAROO POINT

HILLARYS

Hillarys Beach Sector

LEGEND

BUSHLAND CONDITION SCALE

Very Good - Excellent
80 -100% Native Flora composition
Cover/abundance of weeds less than 5%
Minor signs of disturbance

Fair - Good
50-80% Native Flora composition
Vegetation structure modified or nearly so.
Disturbance influence moderate.
Cover/abundance of weeds 5-20%

Poor
20-50% Native Flora composition.
Vegetation structure completely modified.
Disturbance incidence high.
Cover/abundance of weeds 20-60%

Very Poor
0-20% Native Flora composition.
Vegetation structure disappeared.
Disturbance incidence very high.
Cover/abundance of weeds 60-100% cover

Recently Burnt

DUNE BLOWOUT / EROSION

REHABILITATION ZONE

CADASTRE

TRACKS

SECTOR BOUNDARY

N

100 0 100 200 300 400 Meters

• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL CC ANTS
9 Stirling Highway North Fremantle Western Au 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

JOINS FIGURE 4(e)

JOINS FIGURE 4(b)

FIGURE 4(c): Bushland Condition, Weed Invasion and Dune Erosion

"Pinnacles"

Pelargonium capitatum

North Mullaloo Sector

OCEAN REEF ROAD

Large areas of bare sand.
Grassy weeds up to 50% cover.

MAP SHEET LAYOUT

4(a)
4(b)
4(c)
4(d)
4(e)
4(f)

N

100 0 100 200 300 400 Meters

INDIAN OCEAN

Tetragonia decumbens to 60%.
Pelargonium capitatum to 50%.

Mullaloo Beach Sector

Up to 50% Lagurus ovatus

OCEANSIDE PROMANADE

MULLALOO

MULLALOO BEACH

Avena barbata to 80%.
Lagurus ovatus to 50%.

Alot of bare sand in this area.
20% Tetragonia decumbens.

MULLALOO DRIVE

KALLAROO

Whitfords Beach Sector

LEGEND

BUSHLAND CONDITION SCALE

Very Good - Excellent
80 -100% Native Flora composition
Cover/abundance of weeds less than 5%
Minor signs of disturbance

Fair - Good
50-80% Native Flora composition
Vegetation structure modified or nearly so.
Disturbance influence moderate.
Cover/abundance of weeds 5-20%

Poor
20-50% Native Flora composition.
Vegetation structure completely modified.
Disturbance incidence high.
Cover/abundance of weeds 20-60%

Very Poor
0-20% Native Flora composition.
Vegetation structure disappeared.
Disturbance incidence very high.
Cover/abundance of weeds 60-100% cover

Recently Burnt

DUNE BLOWOUT / EROSION

REHABILITATION ZONE

CADASTRE

TRACKS

SECTOR BOUNDARY

• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL C TANTS
9 Stirling Highway North Fremantle Western Australia 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

JOINS FIGURE 4(d)

JOINS FIGURE 4(a)

FIGURE 4(b): Bushland Condition, Weed Invasion and Dune Erosion

Iluka Foreshore Sector

Ocean Reef Sector

North Mullaloo Sector

OCEAN REEF HARBOUR

OCEAN REEF

OCEAN REEF ROAD

HODGES DRIVE

Abundant grassy weeds around path, including Bromus diandrus, Avena Barbata and Lagurus ovatus.

Arena barbata 50%
Euphoria terracina 10%

Trachyandra divaricata 30%,
Brassica tourneforti 10%,
Lagurus ovatus 10%,
Bromus diandrus 10%.

Abundant grassy weeds.

MAP SHEET LAYOUT

4(a)
4(b)
4(c)
4(d)
4(e)
4(f)

LEGEND

BUSHLAND CONDITION SCALE

Very Good - Excellent
80 -100% Native Flora composition
Cover/abundance of weeds less than 5%
Minor signs of disturbance

Fair - Good
50-80% Native Flora composition
Vegetation structure modified or nearly so.
Disturbance influence moderate.
Cover/abundance of weeds 5-20%

Poor
20-50% Native Flora composition.
Vegetation structure completely modified.
Disturbance incidence high.
Cover/abundance of weeds 20-60%

Very Poor
0-20% Native Flora composition.
Vegetation structure disappeared.
Disturbance incidence very high.
Cover/abundance of weeds 60-100% cover

Recently Burnt

DUNE BLOWOUT / EROSION

REHABILITATION ZONE

CADASTRE

TRACKS

SECTOR BOUNDARY

N

100 0 100 200 300 400 Meters

• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL CONSULTANTS
9 Stirling Highway North Fremantle Western Australia 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

JOINS FIGURE 4(c)

FIGURE 4(f): Bushland Condition, Weed Invasion and Dune Erosion

JOINS FIGURE 4(e)

WEST COAST DRIVE

SORRENTO

SORRENTO BEACH

ROBIN AVENUE

ROSS AVENUE

CLONTARF STREET

HIGH STREET

BEACH STREET

Pelargonium capitatum 50%,
Tetragonia decumbens 50%.

Up to 50% bare sand in parts.
Tetragonia decumbens to 50%,
Pelargonium capitatum to 20%,
Bromus diandrus to 20%.

Pelargonium capitatum to 80%,
Tetragonia decumbens to 40%,
Bromus diandrus to 20%.

Sorrento Beach Sector

Pelargonium capitatum to 50%,
Tetragonia decumbens to 40%.

Marmion Beach Sector

Pelargonium capitatum to 60%

INDIAN OCEAN

MARMION BEACH

MAP SHEET LAYOUT

4(a)
4(b)
4(c)
4(d)
4(e)
4(f)

N

100 0 100 200 300 400 Meters

LEGEND

BUSHLAND CONDITION SCALE

Very Good - Excellent
80 -100% Native Flora composition
Cover/abundance of weeds less than 5%
Minor signs of disturbance

Fair - Good
50-80% Native Flora composition
Vegetation structure modified or nearly so.
Disturbance influence moderate.
Cover/abundance of weeds 5-20%

Poor
20-50% Native Flora composition.
Vegetation structure completely modified.
Disturbance incidence high.
Cover/abundance of weeds 20-60%

Very Poor
0-20% Native Flora composition.
Vegetation structure disappeared.
Disturbance incidence very high.
Cover/abundance of weeds 60-100% cover

Recently Burnt

DUNE BLOWOUT / EROSION

REHABILITATION ZONE

CADASTRE

TRACKS

SECTOR BOUNDARY

• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL CONSULTANTS
9 Stirling Highway North Fremantle Western Australia 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

2.6 Conservation Values

2.6.1 *Bush Forever*

The draft *Perth's Bushplan* (Government of Western Australia, 1998) has been finalised, and was released as *Bush Forever* (Government of Western Australia, 2000). This document applies specifically to bushland within the Swan Coastal Plain portion of the Perth metropolitan region. Bushland areas listed as *Bush Forever* sites have been recognised as having regional conservation value. Most of the study area falls with *Bush Forever* site 325 (Coastal strip from Burns Beach to Hillarys), which extends from north of Hillarys Boat Harbour to the northern limit of the study area (Figure 1).

As part of the *Bush Forever* process, specific criteria were developed to select coastal areas in the metropolitan region suitable for conservation areas. The six criteria relate to:

- Inclusion of a succession of different Quindalup dune types;
- The requirement for the site to be of sufficient size that natural processes such as dune formation can continue;
- Inclusion of sandy and/or rocky shorelines;
- Linkage to other bushland or coastal areas;
- Possession of a variety of vegetation types; and
- Possession of a variety of adjacent habitats to provide for the diverse reptilian and bird fauna of the coastal dunes.

Bush Forever Site 325 was constrained in meeting all of these specific coastal reserve criteria, but four were met to a limited extent. These included:

- The presence of a variety of Quindalup dune types, although predominantly the younger dune types with few of the older phases of dune formation represented;
- The capacity for continuing natural processes, with the site being 214.7 ha in area, with 146.1 ha of bushland, extending to a maximum of 0.8 km inland;
- Inclusion of soft (sandy) and hard (rocky) shorelines, with the vegetated areas south of Burns Beach considered to be the best remaining example of a "limestone ridge forming cliffs" in the north west corridor of the Perth Metropolitan Region; and
- Linkage, as part of a semi-contiguous north-south vegetated coastal strip.

The recommendation in *Bush Forever* regarding Site 325 was that "the existing care, control and management intent of the reserve is endorsed. The purpose of the reserve should be amended to include conservation and appropriate mechanisms applied in consultation with the management body" (Government of Western Australia, 2000).

2.6.2 System 6

The northern section of the study area, from Burns Beach to north of Mullaloo Beach (with Korella Street marking the approximate southern boundary) was recommended as a conservation reserve in the System 6 report (Department of Conservation and Environment, 1983), as part of M2, which extended north to Two Rocks Open Space.

The System 6 report noted that the area is important in conserving a diverse and relatively undisturbed coastal environment. The sand dunes were considered to be important wildlife habitats, containing special features such as limestone pinnacles. The section of M2 south

of Burns Beach was noted as being of special conservation value, with limestone sea cliffs dominated by unusual species, including *Frankenia pauciflora* (Department of Conservation and Environment, 1983).

The high conservation values and popularity with recreational users give the M2 area regional significance. The System 6 report recommended that the area's management required co-ordination enhance the conservation and recreational values of the area. Management considerations raised in the report included preventing erosion, providing adequate car parks, boat ramps, life-saving stations and fenced access to the ocean, restricting recreation to areas compatible with conservation of flora and fauna, and recognising the area's mineral potential.

2.6.3 Adjacent Marine Areas

System 6 area M10: Offshore reefs – Ocean Reef to Trigg includes the marine area from Trigg Island (which lies south of Marmion Beach, the southern limit of the present study area) to Ocean Reef. The coastal boundary of M10 lies at the high water mark, and it includes an offshore reef and series of several smaller reefs. The reefs in this area were noted as biologically rich and unsurpassed in the local area as an underwater spectacle. In addition to high conservation value, the area was noted as having educational and recreational value, and it was recommended that M10 be established as a Marine Reserve (Department of Conservation and Environment, 1983).

Marmion Marine Park, an A Class Reserve, was established between Trigg Island and Burns Beach in 1987, Western Australia's first Marine Park. There are three sanctuary zones within the Marine Park. The park supports a wide array of marine life, including many fish such as Western Blue Devils, Old Wives, Banded Sweep, Crested Morwong, Horseshoe Leatherjackets and Wrasse, and has a number of popular recreational diving locations. Bottlenose Dolphins and Australian Sea Lions are common within the park boundaries (CALM, 2002).

2.6.4 Linkage

The study area has important linkage value, with adjacent bushland to the east in some areas, and as part of a regionally significant fragmented bushland/wetland linkage (Government of Western Australia, 2000). The study area is also part of Greenways 1, 4 and 10 in *A Strategic Plan for Perth's Greenways* (Alan Tingay and Associates, 1998). Greenways can be defined as "networks of land containing linear elements that are planned, designed and managed for multiple purposes including ecological, recreational, cultural aesthetic, or other purposes compatible with the concept of sustainable land use" (Ahern, 1995). In urban areas, greenways can provide linear linkages between more substantial bushland and coastal reserves.

2.6.5 National and International Significance

Although the study area is of high local and regional significance as listed above, no values of national or international significance have been identified (Government of Western Australia, 2000).

2.7 Aboriginal and European Heritage Values

A search of the register of Aboriginal sites requested by the City of Joondalup found one site on the Permanent Register of Aboriginal Sites. This site was an artefact site located in the northern section of the Mullaloo Desert, close to Oceanside Promenade. The search results are given in Appendix Two.

A number of historic sites of European heritage have been identified within the study area. A plaque in Geneff Park, near Sorrento and Marmion Beach, commemorates the whaling station established at Marmion in 1849, although all traces of the buildings have now disappeared (Woods, 1984b).

A number of historic water holes and a spring are located either within or adjacent to the study area. The Gumboya and Whitfords water holes were located to the east of West Coast Highway, outside the study area. Burns Spring was located south of Burns Beach Road, and probably lies within the northern portion of the study area (Woods, 1984b).

Recreational use of some parts of the study area dates from at least the early 1920s (City of Wanneroo, 1991). In 1925 the first recreational shack was built at Mullaloo Beach following the extension of the coastal track from North Beach into the area.

2.8 Recreation and Access

The dunes, beaches and marine areas of the Joondalup foreshore are used for a number of recreational pursuits, including walking, jogging, cycling, skating, animal exercising, swimming, surfing, diving, waterskiing, sailing, windsurfing, fishing and boating. A dual-use path has recently been finished that runs for almost the entire length (minus 100 metres) of the 14 km of coastal foreshore within the City of Joondalup. This path is well used by pedestrians and cyclists. Designated parks with facilities such as substantial carparks, play equipment, barbeques, toilets, tables and chairs are located at a number of nodes along the foreshore, including:

- Iluka Foreshore, at the end of Shenton Avenue, with small grassed areas with seating and barbeques;
- Tom Simpson Park, adjacent to the study area at Mullaloo Beach;
- Pinnaroo Point and the Animal Exercise Beach off Whitfords Avenue;
- Whitfords Nodes, the coastal portion of which is included in the study area, at the southern end of Hillarys Beach, north of Hillarys Boat Harbour.

Popular swimming beaches with large carparks, kiosks, shower blocks, infrastructure and surf lifesaving clubs are located at Mullaloo, Sorrento, Whitfords and Hillarys marina. Other sections of the beach have smaller carparks, although it has been noted that particularly in the North Mullaloo and Whitfords areas, the capacity of these carparks is regularly exceeded. Much of the length of the dual use path is fenced on at least one side. A number of east-west access paths to the beach occur along the length of the coastline, constructed of varying materials including sand. Many of the beach access paths are also fenced.

3.0 Review of Management Plans

Joondalup Coastal Foreshore Natural Areas Management Plan

The Department of Planning and Infrastructure has recently released the draft report on the *Status of Coastal Planning in WA 2001/2002* (DPI, 2001), which contains useful information on the requirements for coastal planning in the metropolitan region, as well as throughout the state. Up to the present time, there has been little strategic planning for coastal management in the metropolitan area, with a greater emphasis placed on localised planning within the boundaries of management responsibility (DPI, 2001). This has particularly been the case for the coastal areas of the City of Joondalup, including former parts of the City of Wanneroo, which have been the subject of numerous coastal plans covering different stretches of coast. DPI (2001) point out that many of these foreshore management plans have been prepared and implemented by developers as part of the development approval process. However, as developments have matured, the pressures on coastal areas have altered, along with patterns of use. The coastal northern suburbs have experienced considerable development pressure over the past two decades, which has in turn placed pressure on coastal resources. Many of the existing coastal foreshore management plans for the City of Joondalup are older than those prepared for the City of Wanneroo to the north. Many of the older foreshore management plans need to be reviewed to ensure that management, which has subsequently become local government responsibility, is appropriately guided.

This section of the report contains a review of existing management plans produced for coastal areas within the study area, and also of management plans produced for neighbouring coastal areas in the City of Wanneroo to the north, and the City of Stirling and Town of Cambridge to the south.

3.1 City of Joondalup and City of Wanneroo

A number of management plans for coastal areas within the City of Joondalup (some of which were formerly in the City of Wanneroo) and the City of Wanneroo exist, some of which have been reviewed in this document, including:

- Coastal Nodes Development Plan Report (Scott and Furphy Engineers, 1979);
- Local Coastal Management Plan Wanneroo Sectors 2 and 3 Sorrento to Burns Beach (Woods 1984a);
- Results of the Wanneroo Coastal Study with Draft Goal, Objectives and Recommendations for a Coastal Management Policy (Woods, 1984b);
- Pinnaroo Point Foreshore Management Plan (City of Wanneroo, 1990);
- Hillarys Beach – Hillarys Park Foreshore Management Plan (City of Wanneroo, 1991a);
- Whitfords Beach Foreshore Management Plan (City of Wanneroo, 1991b);
- Public Environmental Review (PER) for the Proposed Residential Development of the Western Cell Lot 2 Burns (Halpern Glick Maunsell, 1995);
- Mullaloo – Ocean Reef Foreshore Management Plan (Tract and Kinhill Engineers, 1995); and

- Silverton Limited – Quinns Rocks Estate Stage 1 Foreshore Management Plan (Alan Tingay *et al*, 1996).

Some of these reports were referred to in the draft *Status of Coastal Planning in Western Australia 2001-2002* (DPI, 2001) as follows:

- Ocean Reef Foreshore Management Plan (1985): As the document is now 17 years old, it is in need of review to ensure management needs are met;
- Foreshore Management Plan for Mullaloo Point (1989): City of Joondalup indicated that this document remains very relevant to current management needs. DPI (2001) suggests that a general review of the document is warranted as it is 13 years old. A combined Foreshore Management Plan for Mullaloo and Ocean Reef was produced in 1995 and contains good detail on the priorities for conservation and recreation; and
- Pinnaroo Point Foreshore Management Plan (1990), Whitfords Beach Foreshore Management Plan (1991), Hillarys Beach – Hillarys Park Foreshore Management Plan (1991): City of Joondalup has indicated that these documents are still relevant to management needs, however a general review of the documents would be beneficial.

3.1.1 Need for Review of Foreshore Management Plans

Foreshore management plans develop guidelines for a particular beach, bay, inlet, or section of a foreshore, and are usually more detailed than local government area-wide coastal management plans. The life of foreshore management plans is generally about five years, at which time a review of the success and implementation status of management recommendations should be undertaken. All of the foreshore management plans covering portions of the Joondalup coast are more than five years old, and in many cases significant population increases in neigbouring suburbs have occurred since management plans were written. The population in the City of Wanneroo increased from approximately 80 000 in 1979 to approximately 170 000 in 1990, with 147,000 residents in the City of Joondalup in 1999. The City of Joondalup has experienced considerable development pressure over the past two decades. The coastal areas of the City of Joondalup are a valuable recreation and conservation resource, but the existing management plans are generally over ten years old, and have not been able to account for the increase in population and changing demographic trends.

Land uses have also changed during this period, with less emphasis on resource extraction (for example mining and groundwater extraction) and environmentally damaging recreational pursuits such as four-wheel driving and sandboarding, and more emphasis on conservation, revegetation and passive recreational developments. *Bush Forever* (Government of Western Australia, 2000) has also been released since the management plans were written. *Bush Forever* puts the conservation of important bushland and coastal areas into a planning framework. The dimensions of the coastal reserve had not yet been determined when the previous management plans were written, with some plans showing areas of potential future urban development that are now part of the coastal reserve, within the boundaries of the *Bush Forever* site.

Many of the management plans have the placement of recreational facilities as a central theme, with attention paid to weighing up alternative locations for proposed marinas, buildings, hotels, roads, groynes, rock walls, carparks, recreational nodes, and proposed alignments for dual-use paths. Many of these developments and pathways have now been

built, and many of the areas proposed for revegetation under previous management plans have now been attended to, with a high degree of success in many locations, such as in coastal heath north of Mullaloo, at Whitfords beach, and east of Pinnaroo Point. A review of the management plans would allow for an audit of revegetation programs, and assessment of the impact of realised developments in beach precincts.

3.1.2 Scope and Purpose of Existing Plans

The Coastal Nodes Development Plan Report (Scott and Furphy Engineers, 1979), and the Foreshore Management Plans for Whitfords Beach (City of Wanneroo, 1991b), Hillarys Beach (City of Wanneroo, 1991a), and Sorrento to Burns Beach (Woods, 1984a) concentrated on outlining the management issues affecting each area, and then proposing suitable strategies and courses of action for management. These reports aimed to provide a guide to the resources of each sector of coast; and the constraints which will limit use of these resources (Woods, 1984a). The range of possible future developments in the coastal zone was considered in each report, along with a strategy and guidelines for appropriate development (Scott and Furphy Engineers, 1979).

Two of the management plans noted that an effective foreshore management plan should provide guidance for development control, work programmes, the creation of protection or conservation units and control of land uses. Foreshore management plans should achieve a balance between the protection of environmental quality, and the satisfaction of social and economic demands (City of Wanneroo, 1991a; 1991b). Each of the management plans aims to achieve this by considering the relevant characteristics and needs of the coastal zone, and the specific features of the area of coast dealt with in each plan.

The Foreshore Management Plan for Quinns Rocks (Alan Tingay and Associates *et al*., 1996) and the PER for the Burns Beach Development (Halpern Glick Maunsell, 1995) deal with impending proposed developments. These reports aim to evaluate the environmental impacts of proposed residential developments, and to propose specific management strategies for the foreshore reserve.

The Wanneroo Coastal Study (Woods, 1984b) is a more general document, aiming to provide a guide to future use and management of the coastal zone. This document compliments the more specific management plans by providing a broad planning framework for future developments affecting the coast.

3.1.3 Existing Management Strategies

General Policies

In 1984, when the last comprehensive management plan for the entire Joondalup foreshore was written (Woods, 1984a; 1984b), the City of Wanneroo controlled the management of coastal reserves, and planning in the area. The City and Public Works Department managed beaches where erosion control works were required, and all waters within Ocean Reef Marina, and offshore waters were controlled by the (then) Department of Marine and Harbours.

Existing management plans refer to designated Regional Open Space (ROS) in coastal areas. ROS was intended to include, as a minimum, the existing coastal reserve and dune management and erosion prone zones. The purpose of ROS was to:

- Prevent private ownership of land subject to erosion (most important on a sandy coast);
- Maintain a viable dune/vegetation system to prevent inland movement of sand;
- Ensure public access to the coast and space for back-up facilities. The favoured option was a series of scenic roads running parallel to the coast, and maximisation of public access;
- Keep options open by retaining sufficient space behind the coast for appropriate developments; and
- Preserve selected areas for landscape, views and scientific purposes.

Development Setbacks

With respect to development, both the Whitfords and Hillarys Management Plans (City of Wanneroo, 1991a; 1991b) recommended the following restrictions:

- Where the coastline is stable or accreting, a setback of 100 metres from the line of permanent vegetation as a guideline; and
- Where the coastline is regressive, the reserve should include a recession component in addition to the basic 100 metre setback using a 100 year timeframe.

The Wanneroo Town Planning Scheme current in 1984 (Woods, 1984b) recommended that in order to preserve and protect against development which could destroy the existing physical characteristics of flora adjacent to the coast, no development except a public road or a building for the use or convenience of the general public should be allowed within 90 metres of the seaward crest of a stable sand dune undisturbed by wind or wave erosion.

Management Units

Many of the existing management plans make reference to defined management units, in order to determine the most appropriate management techniques and land uses for areas with common characteristics. Typically, management units included areas set aside for conservation, where development should be kept to a minimum, areas set aside as a setback zone from the coast due to erosion and the need for dune preservation, and areas where the main focus was to be passive recreation, with some facilities provided.

Woods (1984a) produced a Concept Plan that defined the following sectors:

- Minimum Regional Open Space (including a dune management zone and the extent of the 200-year erosion prone zone);
- Preservation Units (including coastal heath south of Burns Beach, the “Pinnacles” or “Little Desert” north of Mullaloo beach, the dunes south of Mullaloo, and the dunes behind the Whitfords Nodes); and
- Areas with development potential behind stable coast (this included much of the Ocean Reef area and some coastal vegetation north of Burns Beach that is now degraded); and
- A reef management zone off shore.

The Whitfords and Hillarys foreshore management plans (City of Wanneroo 1991a; 1991b) also recommended the designation of areas of coast into separate management units.

These units were preservation units, conservation units, amenity units and beach units. The management plan for Whitfords also included areas that required special attention for revegetation programmes. Preservation units consisted of younger coastal dune formations, including the coastal development setback. This area was designed to be a protective buffer, and no development was allowed except for carefully designed and fenced beach access paths. Conservation units were intended to protect the natural quality of dune landscape, and preserve its high educational value. Access-ways were the only allowed development. Amenity units were intended to facilitate the construction of carparks, and toilets, change-rooms and showers. Beach units were for active and passive recreational use. Beach units were defined as being between the low and high water marks, with no vehicle access permitted, except emergency vehicles. The Hillarys foreshore management plan (City of Wanneroo, 1991a) then separated the Beach unit into Recreation, Animal Exercise and Small Boat Launching Sub-Units (City of Wanneroo, 1991a; 1991b). Both the Hillarys and Whitfords foreshore management plans provided greater detail and definition of units than the Wanneroo Coastal Study (Woods 1984a), due to differences in the scale and objective of the plans.

3.1.4 Management Issues

Use Pressures

Many of the issues facing coastal managers relate to use pressures. In the Wanneroo coastal area, there are a number of use pressures that could conceivably cause problems with competition for resources and space. One of the most relevant is population growth in the northern suburbs. The population of the City of Joondalup was 147,000 in 1999. With an increasing number of people residing in the northern suburbs, there will be a greater number of people utilising coastal areas, and with this increased use will come greater demand for formal access. The potential for competing beach use and increased pressure on coastal resources from activities such as commercial and amateur fishing, boat launching, tourism, waste disposal, mining and quarrying will increase in relation to the population. An increased amount of coastal use will also result in greater demand for access facilities, such as carparks, lookouts, beach paths and bike tracks,

It is however important that the conservation of dunes, coastal heath and reef systems is not compromised. If this is to be achieved, management plans will need to consider the likely pressures and resulting impacts on local natural systems, and ways to manage these (Woods, 1984a).

Erosion and Instability of the Coast

The sandy coast between Sorrento and Mullaloo fringing the Whitfords Plain is likely to be subject to major changes in the long term (as opposed to the rocky coast south of Sorrento and north of Mullaloo). The stretch of coast between Sorrento and Pinnaroo Point is considered to be stable to eroding, while the coast between Pinnaroo Point and Mullaloo is considered to be stable to accreting (Woods, 1984b). The most effective management solution to this problem is to ensure that no unsuitable developments are undertaken in erosion-prone areas. Consideration of areas of coast that are eroding is important to the formulation of dune restoration strategies, so that appropriate strategies can be used. For example, many dune restoration strategies rely on supply of sand to the coast, and will be less successful along eroding stretches, where there is no steady sand supply.

If dunes are degraded or destabilised, prompt action is usually required to arrest the problem. Revegetation programmes should be established with emphasis on blowouts, and where vegetation has been damaged. All dune areas should be fenced into polygons separated by access paths, and all lookouts should be properly fenced (City of Wanneroo, 1991a; City of Wanneroo, 1991b), and rabbit control may be necessary in some areas (Alan Tingay and Associates *et al,* 1996).

Rehabilitation and Revegetation

Restoration of dune vegetation was considered of high importance due to the role it plays in inhibiting coastal erosion processes. Revegetation was regarded as a critical part of the restoration process necessary for long-term stability of dunes. The use of native plant species was recommended for revegetation as they are successful colonisers and have a considerable capacity to regenerate.

Steep dunes and unofficial access paths were identified as requiring rehabilitation in the Mullaloo-Ocean Reef Coastal Management Plan, (1995), while the Whitfords Beach Coastal Management Plan (1991) recommended that revegetation programmes be established where dune blowouts had occurred and where vegetation has been damaged. The Hillarys Beach/Hillarys Park Management Plan (1991) recommended that revegetation programmes be established with emphasis on coastal areas damaged by animals and in the vicinity of lookouts.

Conservation Areas

The coastal heath south of Burns was mentioned by a number of reports as warranting conservation. The suggested management actions were to prevent vehicular access and erosion, to provide access to the ocean and to encourage recreation activities compatible with conservation of flora and fauna. There were some issues involved with setting aside such a large area of heath for conservation as there would be high acquisition and management costs, and a potential increased fire hazard (Woods, 1984a).

In 1983 the EPA recommended that the coastal strip between Mullaloo and Two Rocks be managed as a regional park due to its high conservation values and popularity. The Mullaloo-Ocean Reef Foreshore Management Plan (1995) recommended that this area be managed for conservation as it forms part of the System 6 estate. The EPA also recommended that a broad area of offshore reef between Trigg Island and Ocean Reef be established as a marine reserve. This area became Marmion Marine Park in 1987.

Access

Access issues have been identified in the past and measures have been put in place to control access to the beach in order to prevent environmental damage. Access-ways should be constructed in such a way that they are robust and do not encourage wind erosion, and signs should be installed to inform beachgoers of access paths destination and length, and of erosion risk areas.

It was mentioned in the Whitfords Management Plan that the pathways from the carpark should be upgraded, the paths connecting Northshore Drive with the beach should be fenced, and a dual use path be constructed between Hillarys and Mullaloo. There was also

mention of one particular beach access path that needed attention as it washed away every winter. A possible solution to this problem would be to construct a more permanent path of parallel logs connected by two chains (City of Wanneroo Town Planning Department, 1991b).

There has also been a problem of unofficial access paths. Management plans have previously identified unofficial access paths as causing degradation to dunes and vegetation. Control measures suggested include fencing of official access paths and signage warning of danger of limestone cliffs or damage to dunes. Recently additional measures have been put in place to cope with determined use and creation of unofficial access paths involving brushing in areas of repeated use.

Fencing

Fencing was considered an important part of restricting access to keep people away from sensitive areas with post and wire fences regarded as the most successful in dune areas. The expense of fencing was identified as an issue in the Hillarys and Whitfords Beach Management Plans, as fencing requires continual maintenance, repair and replacement. Changes in the shoreline and dune movement were also considered a difficulty in the construction and maintenance of fencing. For this reason it was recommended that fences should be erected several metres back from the cliff-like edges but still visible to the beach. It was also recommended in the Mullaloo/Ocean Reef Foreshore Management Plan that access gates to fences dune areas be provided for maintenance purposes.

Fire

Fires in coastal areas compromise safety, and can have a significant effect on dune ecosystems. To lessen the risk of a large fire becoming established in the dunes it was recommended that all pathways should have a fire resistant surface, and be kept free of vegetation so as to act as firebreaks (City of Wanneroo Town Planning Department, 1991b). It was also suggested that fuel reduction buffers be applied to strategic protection units such as accessways, dual use paths and car-parks.

3.2 City of Stirling and Town of Cambridge Coastal Foreshore Reports

This section contains a review of coastal foreshore management and planning in the City of Stirling and Town of Cambridge, located south of the City of Joondalup. The City of Stirling has a coastal report that was last reviewed in 1996. The report supplements internal procedures such as a five-year works programme and annual hazard remediation programme that are approved by the city's Coastal Management Advisory Committee (DPI, 2001). The draft *Scarborough Environs Study* was released for public comment during 2001. DPI (2001) recommended that local foreshore management plans should be developed for areas within the City of Stirling, including the northern bay beaches (such as Waterman's Beach and North Beach), Trigg Beach, South Trigg Beach, Scarborough Precinct and Brighton Beach. The Town of Cambridge has a coastal management plan developed in 1998, which is providing adequate structured management direction on coastal issues (DPI, 2001).

3.2.1 City of Stirling Coastal Report

The coastal report for the City of Stirling was published in 1984 and is a large-scale analysis of the coastal environment, management issues and implementation of the entire foreshore within the City of Stirling. This section of coastline is one of the most heavily used sections of the Perth metropolitan coast. The aim of the report was to provide an integrated analysis of the entire foreshore so that a comprehensive approach to coastal management and development could be obtained, as opposed to the *ad hoc* strategies applied to individual beaches and coastal sections. The report suggested management strategies based on the entire foreshore in the City of Stirling as well as individual 'management plans' for all of the subdivisions, denoted sectors.

The key issues of coastal management and development identified by the report are 'utilisation' and 'conservation'. Utilisation referring to the use of land for urban purposes and recreational activities, and conservation was concerned with the management and preservation of the land's natural state.

Land Use Issues

The main issues identified in the report were divided into geomorphological problems and problems arising from land-use practices.

The geomorphological based problems were:

- *Foredune erosion* caused by marine and aeolian erosion processes, which may trigger dune degradation;
- *Dune degradation* caused by wind action on unconsolidated sand due to a lack of dune vegetation, causing dune movement inland. Minor problems also exist near beach access-ways and stormwater discharge areas;
- *Deflation hollows on dunes and slopes* caused by the above effects but remedied by the city's dune restoration; and
- *Headland and cliff degradation.* A widespread problem of mechanical and chemical weathering of the Tamala Limestone. Major problems identified at Trigg Island and North Beach.

Beach management problems associated with geomorphological change identified in the report are summarised in Table 3.

The problems arising from land-use practices were identified as:

- *Recreational Pressures.* Environmental degradation as a result of excessive use of beach resources leading to a reduction in recreational and scenic amenity;
- *Inadequate provision of facilities* occurring where high use is not matched by increased facilities. Increased facilities may lead to increased use aggravating other problems;
- *Inappropriate development* causing negative environmental impacts. For example, development in unstable hazard areas and development causing reduction of visual amenity of the area;
- *Damage and erosion of coastal engineering works.* This can occur as a result of normal beach fluctuations or accelerated erosion due to recreational pressure, inappropriate locations of engineering works and recreational pressure;
- *Low aesthetic value.* Visual impact of surrounding structures lessens the overall attractiveness of the coastline; and
- *Inappropriate management policies* that do not provide a long term solution or that may compound other problems.

Table 3: City of Stirling beach management issues, causes and results

Management Issue	Cause	Result
Headland Degradation	• Loss of vegetation cover	• Wind erosion of sand mantling • Exposure of coastal limestone
Shoreline fluctuation	• Winter Storms	• Beach erosion • Damage to facilities, paths and fences
Beach access paths	• Uncontrolled pathways	• Degradation of dune vegetation • Erosion
	• Concrete pathways	• Runoff erosion along edge • undercutting
Deflation and Wind Scour	• Wind erosion • Loss of vegetation	• Deflation of dunes • Dune blowouts
Sand drift accumulation	• Coastal winds	• Covering of roads and paths with sand • Damage to property
Gullying	• Inappropriate placement of stormwater drains	• Damage to paths and nearby installations • Stormwater drain collapse
Mass movement	• Wind scour • Trampling • Wave erosion	• Basal Erosion • Rockfall • Undermining/collapse of walls and pathways
Landfill and Dumping	• Inappropriate positioning of landfills and rubbish dumps	• Gullying • Health Hazard • Decreased amenity

Public Authorities

The report also highlighted the role of public authorities in the implementation of Coastal Management/Development Plans, in particular the (then) Metropolitan Region Planning Authority, the Environmental Protection Authority and Main Roads Western Australia. As half of the project area was Regional Open Space, the MRPA had control of the use and development of the reserve. The MRPA also was identified as having an important role to play in the co-ordination of activities between the Local Authorities and providing an overview of proposed development along the entire length of the metropolitan coast. The Department of Conservation and Environment (now Conservation and Land Management or CLM) also were identified in having an important role in consultation and funding for coastal environmental projects such as dune rehabilitation, in association with the City's Parks section.

Cooperation

Cooperation between departments was also stressed as vital for effective management. Independent decision making often having detrimental effects to other departments and authorities and on the environment of other areas. It was recommended that an authoritative

Coastal Committee be established to examine coastal development proposals, especially when they may have an effect on other foreshore areas.

Funding

It was also recommended that a funding body for coastal projects be established as local authorities rarely had enough funds for upgrading and improving the coastal environment. Local authorities could then negotiate for financial assistance on the basis of its own particular needs. Funding should come from the state government and through organisations and Public Authorities with vested interests or control over any aspect of the coastal reserve.

Coastal Strategy

It was recommended that a coastal management development strategy based on the 'Nodal' structure be implemented. This is where major traffic routes are located 1-2 km inland with selected access to specific points to form development or settlement nodes comprised of:

- Residential
- Recreational
- Commercial
- Industrial
- Other specific

The report pointed to Yanchep, Quinns Rocks and Burns Beach in Wanneroo as excellent examples of the nodal concept. 'Pedestrianising' the Bay Beaches area was also recommended by interlinking pedestrian access paths along the cliffs with individual carparks catering to passive recreation and family groups

3.2.2 Management Plan – Trigg Bushland Reserve (Trigg Regional Open Space) – Department of Parks and Reserves, 1991.

The Management of Trigg Bushland reserve is vested in the City of Stirling. It is an A class reserve with dominant sand ridges representing ancient blowout rims. The vegetation is very diverse and contain significant species including Rottnest Island Pine *(Callitris preissii),* he corky-barked tree *(Gyrostemon ramulosus)* and the Sheoak *Allocasuarina lehmanniana.* The reserve is a breeding ad refuge area for many bird and reptile species. Management issues associated with human impact include:

- Introduction and spread of weeds;
- Introduction of feral animals
- Increased frequency of fire
- Erosion of dune slopes from excessive trampling

Management recommendations included:

- Different management techniques for different discrete sections of the reserve while maintaining reserve as single integral unit.
- Closure of superfluous tracks to reduce weed invasion stemming from tracks. Only tracks necessary for adequate fire management access and recreational use retained

- A policy of fire exclusion in the reserve due to the presence of fire sensitive vegetation, weed invasion, lack of native seed bank and susceptibility of seedlings to fire.
- Weed removal and spread contained through minimal chemical control, manual removal and maintenance of tracks.
- Revision of flora lists.

3.2.3 Coastal Planning Study for the Town of Cambridge – Coastwise, 1998

The Town of Cambridge did not have an overall strategy for ongoing management of its coast prior to this study conducted in 1998. It was commissioned to address several management issues that had arisen over time including:

- Storm damage and loss of beach during severe winter storms;
- Conflict between beach users such as swimmers and surfers;
- The need to review service outlets such as kiosks;
- Native title claims;
- Retention of two surf clubs;
- Beach access conflicts; and
- Car-park rationalisation.

Some of the management issues included in the report are discussed below.

Sand Control

One of the major tasks and costs of beach management is the manual removal of sand blown to the back of the beach back to the front of the beach. A stone wall was built in the 1970's but is an ineffective and outdated coastal management technique. It was proposed therefore to construct a dune in front of the wall to trap sand. Various oppositions to this have been made for reasons of reduced area for recreational use.

People with Disabilities

Beaches were identified as difficult places for disabled people in terms of access as they require hard surfaces for the provision of wheelchairs. Ideas that emerged from the study included:

- Provision of limestone paths to stable dune lookouts
- Provision of sealed walkway or boardwalk from the main car park to South Groyne.
- Provisions of improved kerb crossings and ramps on the edge of steps from car parks.
- Provision of improved access to seating and shade areas
- Provision of access to toilet facilities
- Provision of dedicated parking bays

It was also noted that wheelchair ramps and pathways need to be horizontal rather than sloped, as this requires continual steering correction by the occupant.

Security

A proposed method of increasing security was to encourage more people to use the more remote beach areas. This can be achieved by the installation of recreational facilities, bike paths and walkways. Small recreation areas with children's play equipment could be provided adjacent to car parks to increase public surveillance of these areas.

Landscape and Aesthetics

Shade is an issue which was addressed by this report. *Casuarina equisetifolia* trees, although aesthetically pleasing, were identified as less than ideal as their cones were sharp on bathers' feet. A number of trials showed that these were the only trees that could be successfully established that were of a sufficient size as to afford adequate shade. Many car parks were also identified as being hot and barren with few shady trees. It was suggested that this be broken up by 'islands' planted with *Melaleuca lanceolata.* Selection of uniform colours and styles for seats, bins and picnic shelters signs and park furniture can enhance the visual quality and amenity of the area, and lighting chosen to enhance the visual appeal of the area as well as being functional to night-time users.

Amenities

The provision of beach amenities was identified as contributing greatly to people's enjoyment of the beach. Improved amenities suggested were:

- High mast lighting;
- Children's play equipment with seating and shade for parents and child-minders;
- Skateboarding facilities such as a 'half-pipe' or designed area with obstacles for tricks;
- Beach Showers need to be placed on stable land where they can't get buried by sand; and
- Water Fonts placed strategically to combat dehydration. Beaches can often be harsh environments.

Tourism

The assessment of tourism opportunities is an important part of the diversity and economy of beach areas. The main areas for improving tourism potential were identified as:

- Surf lifesaving clubs enhancing visitor interest and enjoyment, safety and 'dresses up' the beach.
- Kiosks, restaurants and cafes promote the area to visitors as well as providing comfort and catering to the area. In many situations a kiosk, although quite adequate for local use, will not be sufficient to enhance tourism potential. Restaurants should blend in and enhance the natural beauty of the area rather than detract form it.
- Adequate Bus Parking allowing visitors to alight in safety and in view of their destination will attract tourists and tourist operators to the area.
- Information on the natural history of the area as informative signage and interpretation facilities is important for increasing tourist satisfaction. There is also an added benefit of informing local people and regular user about their coastal environment.
- Surfing is often a tourist drawcard in itself and can add to the interest of an area even to non-surfing tourists. Facilities placed at popular surf spots with viewing areas can increase tourist potential.

Rehabilitation and Revegetation

The report highlighted the need for coastal management of dune systems with constant monitoring. The foredune areas of the Cambridge coast have suffered from trampling and sandboarding. These activities exacerbate damage caused by natural storms from which it is normally able to recover. The inclusion of Bold Park into the coastal reserve system was

seen as a positive step in maintaining the natural integrity of the coastline however further steps were identified to rehabilitate degraded areas an prevent further degradation were identified and the following management strategies recommended:

- Fencing should be maintained in good condition
- Adequate pathways to points of interest should be provided
- Informal pathways should be brushed
- Direct planting, seeding and brushing should be used wherever possible
- Plant tube-stock should be used in preference to mature plants
- Indigenous species should be given preference over exotics
- Species diversity should be encouraged
- The Bold Park dune sequence should be used as a model ton which to base species composition and zonation for rehabilitation along the Cambridge coast.
- Signage informing the public of the fragility of the coastal dunes and vegetation should be erected
- People presence and sandboarding in the dunes should be policed

Weed Management

Management strategies for weed control were:

- Manual removal of large exotic species and immediately replaced with native species
- Road and path edges regularly mown to reduce seed production
- Brushing and direct planting of indigenous vegetation close to the vegetation canopy should be an ongoing process.
- Further planting of exotic species within the foreshore reserve should be discouraged.

4.1 City of Joondalup

Maintenance of the foreshore is currently undertaken by the City of Joondalup's Operations Services however there is no designated single work section within the Operations Services Business Unit that is totally responsible for control and management. The works are aligned to specific work teams to maximise experience with work functions and overall efficiency.

4.1.1 Weed Control

Weed control has been identified as one of the biggest environmental problems of the Joondalup foreshore (K. Armstrong, pers. comm.). The main method of control is by application of the grass-selective herbicide Fusilade® carried out regularly in bushland areas, and on an as-needed basis, and the application of Glyphosate® along the sides of paths and extending 30cm on either side. This task is presently contracted to a private company as an annual tender. Larger areas of weed infestation are targeted with herbicide on an as needs basis.

Other weed management involving manual removal is undertaken by various groups and volunteer organisations, particularly Australian Conservation Volunteers, EcoJobs and School groups. This is done on a needs basis aligned to other works, and there is no full-time dedicated group for this activity. Corrective Services also undertakes manual removal of weeds, but this will generally occur in areas where rehabilitation is taking place. Inspections are carried out as part of continual assessment of the foreshore by the Conservation Officer, who also identifies areas in need of control and coordinates work to be carried out.

Cost Effectiveness

The use of private contractors for path spraying is a common practice among the coastal local government authorities and is a very cost-effective means of herbicide application. There is no scope for volunteer groups to carry out this work. A licenced applicator is required for public health reasons.

Volunteer and Corrective Services are often used for the manual removal of weeds primarily as part of rehabilitation projects, which costs very little in terms of actual labour, with only a supervisor needed to oversee operations. Manual removal is unsuitable in many situations as it can damage to surrounding vegetation through trampling or accidental removal of non-target species.

4.1.2 Dune Restoration

Dune restoration and maintenance is generally carried out by community and volunteer groups, including Australian Conservation Volunteers (ACV) and school groups, and by Corrective Services. Some projects have been organised by a body formed from

representatives of various interest groups including the Friends of Marmion Marine Park and the Mullaloo Progress Association. This allows for management of funds and Coastcare grants and organises projects or events. It primarily enables the different groups to be directed by a single body so that funds and effort can be channelled into the areas with the highest values. The peak group is the Joondalup Coastcare forum and was formed from a city initiative in 1999.

Maintenance of dunes is achieved by spreading mulch over the dune surface, hand-raking and brushing which act to slow wind erosion processes. Brushing (the process of laying cut brush on the dune surface), has the added benefit of discouraging people from accessing and damaging the dune surfaces. These activities are mainly conducted by Corrective Services, which is comprised of offenders required to undergo community service by the Justice Department. Rehabilitation of dunes mainly involves hand planting using the city's operations maintenance or capital works funds and Coastcare grants and is primarily carried out by Corrective Services or in-house labour. In 2001, 8,000 plants were set on the Joondalup foreshore. 20,000 plants will be set in 2002 covering an area of several hundred square metres (K. Armstrong, pers. comm., April 2002). Community and volunteer groups undertake dune rehabilitation and planting in small specific areas in high profile locations.

Cost Effectiveness

In terms of effectiveness in preventing dune erosion, brushing is not as effective as mulching along many areas of the Joondalup coastline (K. Armstrong, pers. comm), however it does tend to discourage people from straying on to the dunes and causing additional damage. Mulching is considered more effective at dune stabilisation although it does offer an inviting surface for people to walk on. The added benefit to mulching is that mulch is readily available as a by-product of tree pruning operations elsewhere in the city. A combination of brushing and mulching is used to both stabilise dunes surfaces and discourage people from walking and therefore damaging dunes. For these activities Corrective Services are used, which is very cost effective, however there are drawbacks in that it is difficult to plan projects, as the amount of labour available changes from day to day and is difficult to predict.

Volunteer Organisations, Corrective Services, or local school groups generally carry out dune restoration involving tree-planting or minor restoration work. Restoration conducted by school groups serves a very important role in raising community awareness and education. In general the use of volunteer groups and Corrective Services for dune rehabilitation can often be an effective way to conduct rehabilitation activities at least cost. There is however limited numbers of people willing to volunteer, so a combination of volunteer and professional rehabilitation is therefore needed to produce results at the lowest cost, while still maintaining a high standard of rehabilitation. The city currently has two senior leading hands controlling the Corrective Services crews that are qualified and have extensive experience in maintenance works.

4.1.3 Fencing

There are approximately 40 km of fencing along the Joondalup foreshore (K. Armstrong pers. comm.). Fenced areas include dual use pathways, beach access paths, roads and hazardous areas such as limestone cliffs. Installation of fencing along the Joondalup coastline has generally followed the pattern of housing development from south to north. Consequently the fenced areas in the northern part of the Joondalup foreshore is much newer and in much better condition than fencing in the south.

Aspects of fencing requiring continual maintenance are:

- Holes in fences and broken fences through normal wear and tear;
- Fences cut through vandalism. Dog owners and recreational fishermen have been identified as repeatedly cutting holes in fences to allow access to the limestone cliffs; and
- Fences becoming partially submerged in sand during winter storms.

The Conservation Officer and the senior leading hand in charge of Corrective Services perform inspections of fences as part of the continual assessment of the foreshore areas. Corrective Services carry out a proportion of basic fence maintenance, however drawbacks with this arrangement are that they are generally unskilled and the numbers of people available to work is not constant, however it is very low cost. There is also a city work crew that undertakes fence repair on a day-to-day basis and clears sand from paths and fences when necessary. Contractors are generally used for long stretches of fence repair, or construction of new fences. Operations employees or contractors undertake the major portion of fence maintenance.

Cost Effectiveness

In terms of cost, Corrective Services is very effective. However this source of labour is not exclusively used on the coast but also in other areas within the municipality. Fence repair and other maintenance tasks carried out by Corrective Services, is therefore prioritised and conducted for areas that need the most attention. For this reason fence maintenance and repair in coastal areas can become postponed while higher priority tasks are carried out.

4.1.4 Path Maintenance

All but around 100m of the Joondalup coastal area (c.14 km), is traversed by a dual use path. There are also many beach access paths and ramps, particularly where there is a high concentration of beach users at Sorrento, Mullaloo and Burns Beach. Many of the beach access pathways were installed initially by housing developers and are now maintained by the City of Joondalup. There are also some informal paths that are not maintained and their use is generally discouraged. These often lead to well known fishing spots in dangerous areas on limestone cliffs. Signage and fencing has been installed at many of these areas in an attempt to discourage their use however these attempts are often thwarted.

Path inspection and maintenance is carried out by Operation Services of the City of Joondalup. Maintenance generally involves asphalt and concrete repairs carried out on an as needed basis. Removal of sand using a 'bobcat' is often also required after winter storms. Much of this work is undertaken by contractors on behalf of the City.

Cost Effectiveness

Path maintenance is conducted by Operation Services, with larger works contracted out. No problems have been identified with this arrangement and this is a fairly standard method of managing path maintenance, as the sections responsible for road maintenance can administer path maintenance and construction.

4.1.5 Signage

Much of the coastal signage in place at Joondalup is in the process of being upgraded and improved. Signage is generally located at major beach access points, along dual-use paths and near dangerous areas. Signs are generally either for safety, regulatory or direction. There are no interpretive signs at present however these are planned for the future with a grant from Coastcare in conjunction with other five other coastal cities and shires.

Maintenance is carried out by the City of Joondalup and involves graffiti removal, repairing, repainting, and installation of new signs. Local signwriters are usually commissioned to touch-up signs change lettering and conduct repairs when needed. Signs are normally inspected as part of general inspections of paths and fences.

Cost Effectiveness

New signs are purchased from tendered suppliers and for sign repairs and changes to lettering, the City of Joondalup has found the best option is to employ local signwriters as they have a knowledge of the area and are able to carry out the work at short notice.

4.2 Costs and Benefits of Maintenance Strategies

The costs and benefits in terms of expenditure and quality of work are assessed for the major maintenance strategies in place in the City of Joondalup. These include tenders to outside contractors, commissioning local contractors, the city's Operations Services works crews, Corrective Services, Work for the Dole and community volunteer work including school groups. The maintenance areas each strategy is currently used in are also listed, and additional areas they may be used are highlighted.

4.2.1 Tendered Contractors

Currently used for: Path construction and large-scale repair, fence construction and large-scale repair, weed control along paths, weed control in all natural bush areas.
Could also be used for: Dune restoration.

Costs	Benefits
• Administrative costs in requesting and processing tender applications. • Can only choose amongst submitted tenders	• Least-cost and most effective solutions can be employed. • Exact costs can be predicted • Projects carried out with high degree of efficiency • Contractors have professional knowledge of issues • Public health control and quality control from licenced operators

The tender process enables projects to be carried out with a high degree of efficiency and professional knowledge, however the process of calling for and selecting tenders has a significant cost in itself. Therefore tenders are only really suitable for projects where the administrative costs are outweighed by the benefits of increased efficiency. Contracts that run for three years have been found to be very cost effective.

The areas in which tendered contractors are currently used are suitable, as these projects are of a sufficient size so that increased efficiency outweighs the initial cost. Tendered contractors could also be used in dune restoration. Community groups and Corrective Services personnel currently undertake these areas, however it has been determined that additional work of this type needs to be undertaken of a scope requiring tenders from professional contractors to be called.

4.2.2 Local Small Contractors

Currently used for: Sign repair.

Could be used for: Other small repairs (fences, equipment etc), spot weed control.

Costs	Benefits
• Not guaranteed least cost – most efficient solution • Not practical for large projects • Lack of experience resulting in cost increase	• Knowledge of local area • Can work fast and efficiently on small jobs • No need for supervision • Professional knowledge of solutions

Local small contractors currently are engaged in repairing or changing the lettering on signs. The advantage with this is that they can be on-site quickly as they live in and have a local knowledge of the area. Local contractors may better achieve tasks requiring a level of professional knowledge but which are not large enough to warrant tendering, such as repairs to fences and equipment and localised weed control. Under local government regulations, three quotes must be gathered for projects with a budget of between $5 000 and $50 000. For projects with a value greater than $50 000, tenders must be called.

4.2.3 Corrective Services

Currently used for: minor repairs to fences, minor fence construction, litter removal, dune restoration (tree planting, mulching and brushing), manual weed control.

Costs	Benefits
• Unskilled labour • Require constant supervision • Cannot predict numbers	• Very low cost • Benefits community

Corrective Services are used for much of the unskilled labour undertaken in the City of Joondalup. The work groups are supervised by senior leading hands employed by the City of Joondalup. They are generally used for high priority areas first before lower priority maintenance issues are addressed with the result that low priority maintenance that can be done by Corrective Services will be postponed. Corrective Services personnel are essentially unskilled and should therefore not be used for tasks that require training or are hazardous.

4.2.4 Work for the Dole

Currently used for: fence repairs, dune rehabilitation (tree planting, mulching, brushing), weed control.

Costs	Benefits
• Often unskilled or semi-skilled labour	• Low cost, funded by grants or City funds
• Require constant supervision	• Benefits community
• Short-term funding only	• Provides skills to job seekers

A work for the dole scheme has been used with a degree of success for maintenance and construction activities in Craigie Open Space with participants involved in fence repairs, rehabilitation, revegetation and weed control.

Work for the dole schemes are geared towards installation of capital items, with maintenance ongoing after the schemes finish. The schemes provide participants with a diverse range of skills as well as providing low-cost labour to the City of Joondalup and the general community. It would be beneficial to participants therefore to rotate jobs as much as possible to expose them to a wide range of skills.

4.2.5 Community Volunteers

Currently used for: Dune restoration, revegetation, weed control, litter clean-up days.

Costs	Benefits
• Unskilled or semi-skilled labour although enthusiastic	• Very low cost
• Limited labour force	• Fosters community awareness of coastal issues
• Require supervision and guidance	• Promotes community spirit
	• Facilitates education

Community volunteers have value beyond the work that is achieved, as it is often high profile and can:

- Attract attention to coastal management issues;
- Promote a sense of community togetherness;
- Educate the public and school children on coastal environmental issues;
- Provide skills to volunteers in rehabilitation; and
- Foster a sense of community pride in their environment.

For these reasons volunteer and community involvement in coastal environmental management should be encouraged as well as involvement from school groups. This should not however be the only concession to rehabilitation and revegetation of coastal areas. Large-scale rehabilitation of areas is needed in areas identified elsewhere in this report. A combination of sensible community involvement with consultation and site preparation by professional rehabilitation companies engaged through a tender process is probably the most effective way of carrying this out.

4.2.6 Operations Services Works Crews

Currently used for: Fence repair, equipment and building maintenance, pathway maintenance, beach cleaning, tree planting, mulching, watering, signage maintenance, inspections, rubbish removal, sand drift control, dead animal and fish removal, firebreak construction and maintenance.

Costs	Benefits
• Total cost borne by the city	• Maintenance schedules can be formed and followed • High level of specialist equipment and expertise utilised for maintenance

Operations services works crews are effective at maintenance operations particularly for the diverse array of fencing, buildings, infrastructure and equipment located on the Joondalup foreshore. They do however pose costs that cannot be ameliorated by free labour, as occurs with Corrective Services and Work for the Dole, and are often not as efficient as private contractors. They are primarily used for jobs that are not large enough to warrant tendering but require a higher skill level than Corrective Services or Work for the dole and can also supplement these programs when required.

4.3 Surrounding Local Authorities

4.3.1 City of Wanneroo

The City of Wanneroo is adjacent to the City of Joondalup and until recently was the same municipality. For this reason many of the management schedules in place in Wanneroo are the same as those existing for Joondalup. At this time the Coastal Foreshore Natural Areas Management Plan for Wanneroo is also under review and so maintenance schedules may change in the future.

The maintenance schedule is managed by an electronic system (MAXIMO) developed in conjunction with the City of Joondalup. This system regulates the inspection and maintenance of city works. There is also telephone request systems through which members of the public ring up to identify problems that are then addressed by the city. Periodic inspections of the foreshore occur around every three months to identify and plan future works such as paths, fencing, dune rehabilitation, mulching etc. Larger works and repairs that cannot be fixed by periodic maintenance (such as repeated vandalism), are given an interim solution until funds can be allocated from the budget. This type of periodic maintenance is generally done through city works crews.

Volunteer work is managed through a project and conservation officer who coordinates projects and allocates funding to registered friends groups and is linked to the Conservation Advisory Committee. These friends groups are registered with the city and include the Quinns Rocks Environmental Group, Coastcare and the Surfrider Foundation. Seven of these friends groups are currently registered and organised by the City of Wanneroo. The number of these groups is generally kept under ten so that funds are not spread too thinly. Insurance has also been an issue in the past, as friends groups cannot generally afford their

own insurance. The City of Wanneroo therefore provides liability insurance for approved work on their lands under direction of the city. The city also has links with local schools to help support weed strategies and environmental projects such as tree planting days.

4.3.2 City of Stirling

Coastal management in the City of Stirling comes under the responsibility of the Natural Areas section, who are also responsible for managing wetland and bushland areas. The Natural Areas section manages approximately 7.5 km of coastline, and 58 coastal, bushland and wetland reserves. Their total operating budget is around $500,000 annually, of which around 20% is spent on coastal areas. Of this 20%, around half is spent on rubbish collection, sweeping and related activities, with the other half ($50,000) spent on coastal management such as erosion, weed control, dune restoration, fencing and so on. Funding for coastal works is provided mainly by the City of Stirling, with minimal use of external grants. Funding for Natural Areas is only a small fraction (perhaps 1%) of that available for parks maintenance and management. The Natural Areas section has six full time field staff, as well as a technical officer and co-ordinator.

Community groups and Work for the Dole groups are also involved in coastal activities. The major groups include the Friends of Trigg Bushland and Coastcare. Unlike the City of Joondalup, the City of Stirling does not have a specific community Coastcare group for their section of foreshore. Previously, a Coastal Advisory Committee existed, but this was amalgamated with other groups into the Environmental Advisory Committee. Membership of this group includes Friends groups, councillors, City of Stirling staff members and community members. Community activities on the coast are sometimes co-ordinated through the Natural Areas section, and sometimes co-ordinated by Coastcare.

The entire Stirling coast is inspected three times a week, with a full day spent on Monday cleaning and sweeping. Items that are targeted include rubbish, vandalism and fencing. The signage for the whole coast has recently been upgraded.

Every year, an assessment is made of the entire coastline to determine target areas for weed control, dune restoration, brushing and erosion control. Typically, a number of discrete areas are targeted intensively every year for weed control, replanting and brushing, rather than targeting large areas. In 2002, five sites will be targeted. Between 3,000 and 4,000 plants are planted in coastal areas every year. These plants are generally grown from locally collected seeds, in a nursery operated by the City of Stirling. Seeds are collected every three years. The operation of the nursery has been relatively costly, but it has been retained as it provides the important function of supplying locally sourced plants. In some areas, particularly eroded foredunes, plants have been bought due to a lack of suitable material for germination. The City of Stirling does not use mulch in rehabilitation, and has had problems with securing enough brush for dune rehabilitation works.

The City of Stirling organises an annual inspection of the coast for hazards such as limestone cliffs, and erosion. A geological consultant is hired to inspect the coast, and implementation of recommended remediation works is organised by the Natural Areas section of the City.

4.3.3 Town of Cambridge

The Town of Cambridge lies south along the foreshore adjacent to the City of Stirling. Maintenance of the foreshore area is conducted by the Parks and Landscape section of the Town of Cambridge. Prominent foreshore locations in this municipality include City Beach, Floreat Beach and North Swanbourne Beach.

There are currently no perceived issues of weed control in the foreshore area and no weed removal is conducted apart from around paths and roadsides. Paths and fences are upgraded when they deteriorate or when there is an identified problem and all paths and roadsides are fenced with inspections of paths and fences carried out every month. Most other maintenance issues are addressed on an as needed basis with inspections of carried out at periodic intervals. Signage is currently being upgraded and is generally associated with public safety with some dedicated to sites of interest. A full time beach cleaner is currently employed to remove rubbish and litter from the beach.

There are no dune restoration programs underway at the present time, however Coastcare groups have undertaken some dune restoration projects in the last 23 years, and the Surfrider Foundation also takes part in restoration activities. Parks and Landscape rehabilitation is generally only carried out as part of other projects such as path construction.

5.0 Best Practice Management

The City of Joondalup has expressed interest in ensuring that best management practices are used for the management of the foreshore area. Best practice management means a commitment to improvement of environmental performance. With this in mind, the objective for foreshore management within the City of Joondalup should be to use the most sustainable management practices possible, that result in minimal environmental impacts whilst achieving desired outcomes. The City of Joondalup is in an excellent position to use best practice management of its coastal reserves, as for the most part the coastal area retains a high degree of naturalness in relation to other densely populated coastal areas of Perth, which could be threatened by increasing recreational pressure. In particular, the stretch of coastal heath in the Burns Beach area provides a vivid demonstration of the huge difference between the condition of the Joondalup coastline, and that of popular beaches further south, which generally have a far narrower width of foreshore reserve and do not retain significant native vegetation cover.

This chapter presents a review of some of commonly used management practices for coastal areas relevant to the City of Joondalup. This information has been drawn chiefly from the Oma *et al*'s (1992) *Coastal Rehabilitation Manual*, with supplementary information from South Metropolitan College of TAFE (nd), Bradley (1971; 1988), CALM's (1999) *Environmental Weed Strategy for Western Australia* and other sources. The next chapter gives general recommendations for the uses of these practices in relation to dune restoration, erosion control, revegetation, weed control, access management and fire management along the Joondalup coastline, based on the results of the bushland condition, erosion and weed survey. More specific recommendations for each section of the coast would be more appropriate within foreshore management plans, such as that produced for Mullaloo – Ocean Reef (Tract and Kinhill Engineers, 1995).

5.1 Development of a Coastal Rehabilitation Strategy

There are generally six stages to the development of a coastal rehabilitation strategy, which is a major component of coastal management relevant to vegetation:

1. Identification of the problem and causes of destabilisation;
2. Identification of management options available to address the problem;
3. Determination of the preferred management option;
4. Development of the rehabilitation plan, or the appropriate action;
5. Implementation of the rehabilitation plan or appropriate action; and
6. Monitoring of the site to evaluate the effectiveness of the rehabilitation plan or the action undertaken.

The section of the report below will give information relevant to stages 2 to 6 above. Information relevant to Stage 1 has been provided in the Review section. As general information, Table 4 has been provided, which gives general recommendations from Oma *et al*. (1992) for coastal management by local authorities.

Table 4: Recommendations to local authorities on coastal rehabilitation and management.
Source: Oma *et al*. (1992)

1	Inspect the coast regularly to determine if it is stable or degrading, and to anticipate where problems may develop;
2	Be aware of the likely impacts of development proposals within the coastal environment;
3	Consider the potential impacts of proposed recreational facilities on the coastal environment;
4	Act as quickly as possible to rehabilitate areas before they develop into major problems;
5	Use appropriate rehabilitation techniques;
6	Plan ahead to allow plenty of time to develop the rehabilitation strategy; to maximise community involvement in the process; to ensure sufficient plant stock and seed is available when it is needed; and to ensure that revegetation can be completed early in the growing season so that seedlings maximise their growth;
7	Encourage community involvement in the planning and implementation of the rehabilitation strategy. For example, "Busy Bees", to collect cuttings and pick local seed; to establish a local nursery of coastal plants; or for planting and brushing; and
8	Be committed to the future management of the area and of the coastal environment generally.

5.2 Best Practice Rehabilitation of Coastal Areas

There may be seven components to the rehabilitation of coastal areas:

1. Rebuilding foredunes that have been breached;
2. Brushing or mulching the planted surfaces;
3. Restoration of dune vegetation;
4. Designing recreational areas and access points to the beach;
5. Fencing;
6. Public information and education; and
7. Monitoring and maintenance.

5.2.1 Rebuilding Foredunes

Rebuilding of foredunes may be required in areas where the foredunes have been breached or eroded, as a result of loss of vegetation cover due to either natural or human-induced causes. Rebuilding foredunes prevents further wind funnelling, sand scour and sand transportation inland (Oma *et al.*, 1992). Rebuilding may be achieved by means of earthworks, brush layering or sand trapping fences. The latter two approaches are most relevant to the City of Joondalup, as blow outs are generally localised in nature and in most cases the natural dune formations have not been comprised to the extent that large-scale, urgent reconstruction would be required.

Sand trapping fences may take several years to reform dune faces. The fences work on the principle that wind energy and speed is reduced as it flows over the fence, resulting in deposition of sand behind and downwind of the fence. The eventual height of the resulting dune is as high as the fence itself, with the width between five and ten times the height of the fence. The effectiveness of sand trapping fences depends on wind speed, the amount of sand transported by winds, and characteristics of fence construction (Oma *et al*., 1992). These fences can only be used on stable or accreting coastlines, where there is a steady supply of sand to the beach front. Brush layering works on the same principle as sand trapping fences, with layers of brush added to exposed sand, gradually building the height of the dune. Brush layering is much cheaper than sand fencing, has fewer problems with vandalism, and provides shelter for plant establishment.

5.2.2 Mulching the Planted Surfaces

Once the dune has been revegetated, it is important to stabilise and protect the dune surface as soon as possible. Brushing or mulching protects the young plants and bare surfaces from erosive wind, sand blasting, sand creep and helps to conserve soil moisture, while creating a suitable environment for seed germination and establishment of young plants. Brushing has the added advantage of acting as a reservoir for wind blown sand and is a deterrent to pedestrians (Oma *et al*., 1992).

Traditionally, brushing has been cited as the most effective and usually cheapest method of stabilising the bare sandy surface (Oma *et al*., 1992). On the Joondalup coast however, mulching is more cost-effective than mulch, as pine branch material for brushing is not available. Brushing involves covering the bare dune surface with a single layer of shrub or tree branches, and is particularly suitable for sites exposed to wind. As for sand fences, the presence of brush controls sand movement by impeding the surface wind flow, trapping sand and sheltering plants. *Melaleuca* and pine prunings are ideal brush materials as they retain leaves for long periods, increasing their ability to trap sand and protect the surface (Oma *et al*., 1992). *Eucalyptus* prunings lose leaves quickly, so a denser layer of brush is needed. Prunings of local woody coastal vegetation, such as *Acacia* species, can introduce stocks of local seeds into dunes. Prunings could be sourced from street trees, or from pruning done as part of path maintenance along the foreshore. At present, there is an insufficient supply of material from these sources to be used for brushing.

Mulching with locally available materials, which could include seaweed, will also stabilise sandy surfaces. Mulch has a much lower capacity than brush to trap sand, and will not protect seedlings from sand blasting or wind once pore spaces have been filled (Oma *et al*., 1992). This technique is best used where sand drift and sand blasting are not an issue, in sheltered sites and dune swales.

Experience along the City of Joondalup coast has shown that brush can be easily blown away by the wind, as it contains a large volume of air pockets, along with bulky material such as logs. Brushing also results in increased fire hazard due to the aeration of the material. Mulching is the preferred strategy along the Joondalup coast, as the material is sourced at low cost from pruning of street trees. An alternative, which could be explored if the results of mulching are unsatisfactory, is part way between the two: tritter. Tritter consists of guillotined brush material, which means that brush can lie flatter and interlock more, without as much

pore space. Cuttings of *Acacia rostellifera* make good tritter. This species is locally available and is native to coastal dune areas, which means that seed stocks would be introduced by trittering. Trittering would involve a higher cost than mulch.

5.2.3 Planting Dune Surfaces

Revegetation of degraded dune areas should be done to provide stability to dune surfaces, enhance environmental and conservation values and enhance amenity, and will also reduce the cost of future maintenance of coastal areas by reducing erosion (South Metropolitan College of TAFE, nd). Species suitable for coastal dunes can be divided into primary, secondary and tertiary species, according to their hardiness and proximity to the coast. Primary colonising species should be used on foredunes and mobile dunes, with secondary species used behind the foredunes and mobile dunes. Tertiary species can represent the "climax" stage of dune succession, occurring in more sheltered positions on stable dunes further from the beach.

In some areas of Western Australia, an assortment of native and exotic species are used to stabilise dune surfaces. However, given the conservation objective for much of the vegetation along the Joondalup coast, the use of exotic colonising species is not recommended, with the exception of Marram Grass (*Aremophila arenaria*) and Sea Rocket (*Cakile maritima*). Non-native species are acceptable where the existing plant community includes exotic species, where the proposed introduction offers benefits that surpass the native species (for example, Sea Rocket fulfils a useful purpose by stabilising the exposed strand where few native species can survive), and where it is not an invasive threat to the native plant community (neither of these species are thought to be invasive). It is unlikely that non-native species will be used in rehabilitation along the Joondalup coastline, as grants will not be given to projects that involve the use of non-native species.

It is best to use a variety of indigenous species present, or thought to have once been present, at each area, using locally collected material. Primary colonising species can be used on foredunes and mobile sand dunes, with a combination of primary and secondary species on dunes further from the beach. Cuttings or seed should be collected locally. The timing of first planting should occur when the first winter rains have dampened the sand to a depth of 20-30 cm, generally in June to July. Planting should be completed by the end of the wettest period of the year at the latest (September), bearing in mind that the earlier planting is completed, the better the survival rate.

The sequence for revegetating foredunes and mobile dunes should be as follows:

1. Foredunes and mobile dunes should be planted with *Spinifex hirsutus* and *S. longifolius*;
2. Foredunes and mobile dunes should be seeded and planted with some or all of the other primary dune colonising species in Table 5. Mobile dunes should also be planted with secondary dune colonising species, listed in Table 6.
3. Revegetated areas should be brushed.

Primary colonising species are hardy species adapted to sand blasting, inundation, salt spray and strong winds (see Table 5). The two main native primary colonising species in the Perth coastal area are *Spinifex hirsutus* and *S. longifolius*. *S. hirsutus* is propagated from cuttings, as the seed is not viable in Western Australia. Stem cuttings should be taken from

established plants, and should be 40-60 cm long, containing several nodes. These should be hand planted 30-50 cm deep on a 50-75 cm grid, or more closely (eg 20 cm grid) where sand is accumulating rapidly or where foredunes are steeply sloping (Oma *et al*., 1992). *S. longifolius* is usually propagated from seed, which ripens between November and January. Collection times for other primary colonising species are detailed in Table 5. Seed can be either threshed or scattered across the sand surface before brushing, or the whole seed head is sown on a 50 to 75 cm grid or closer as above with 1-2 cm of the spines protruding. Alternatively, seed heads can be germinated in pots in the dry season and sprouted heads planted out early in the wet season (Oma *et al*., 1992).

Secondary dune colonising species should be re-established on all dunes behind the foredune. Secondary species may also be established on the leeward side of large foredunes. Secondary species should be planted when sands are moist, as for the planting of the foredunes. In general, the two areas would be planted at the same time, with a slightly different planting programme:

1. Seed and plant cuttings or seedlings of the secondary species listed in Table 6;
2. Seed and plant cuttings of the primary species also listed in Table 5 with the secondary species; and
3. Brush.

Table 5: Species to plant on foredunes and mobile dunes

Note that this is not an exhaustive list of all species suitable for use in revegetation programmes. Source: Oma *et al*. (1992) and Kimseed (2001)

Species	Common Name	Growth Habit	Annual or Perennial	Propagation Type	Harvest Time	Seed Cost $/kg (2001)
**Ammophila arenaria* (only if stabilisation cannot be achieved with native colonisers)	Marram Grass	Tufted Grass	Perennial	Culms	June – August	
Atriplex isatidea	Coast Saltbush	Tall shrub	Perennial	Seed	September onwards	110
Isolepis nodosa	Knotted Club-rush	Needle-leaved sedge	Perennial	Cuttings of rhizomes	June – August	638
Lepidosperma gladiatum	Coast Sword Sedge	Sword-leaved, sparsely tufted sedge	Perennial	Culms	June – August	1650
Spinifex hirsutus	Sand Spinifex	Large, clumped spreading grass	Perennial	Cuttings of rhizomes	June – August	28
Spinifex longifolius	Beach Spinifex	Large, clumped grass	Perennial	Seed	December onwards	28

Table 6: Species to plant on secondary dunes

Note that this is not an exhaustive list of all species suitable for use in revegetation programmes. Source: Oma *et al*. (1992) and Kimseed (2001)

Species	Common Name	Growth Habit	Annual or Perennial	Propagation Type	Harvest Time	Seed cost ($/kg)
Acacia cyclops	Red-eyed Wattle	Large shrubs in sheltered areas	Perennial	Seed, seedlings	September onwards, nursery	182
Acacia rostellifera	Summer Scented Wattle	Large shrubs in sheltered areas	Perennial	Seed, seedlings	September onwards, nursery	325
Acacia saligna	Coojong	Large shrubs in sheltered areas	Perennial	Seed, seedlings	September onwards, nursery	83
Acanthocarpus preissii	Prickle Lily	Few-stemmed, prickly, low shrub	Perennial	Seed	September onwards	374
Carpobrotus virescens	Pigface	Succulent ground cover	Perennial	Cuttings	June – August	842
Hardenbergia comptoniana	Wild Wisteria	Creeper	Perennial	Seed	November onwards	270
Isolepis nodosa	Knotted Club-rush	Needle-leaved sedge	Perennial	Cuttings of rhizomes	June – August	638
Melaleuca lanceolata	Moonah	Shrub or tree	Perennial	Seed, seedlings	November onwards, nursery	215
Nitraria billardierei	Wild Grape	Tangled, medium shrub	Perennial	Seed	September onwards	182
Olearia axillaris	Coastal Daisy Bush	Rounded, medium shrub	Perennial	Seed	February onwards	429
Rhagodia baccata	Berry Saltbush	Tangled, medium shrub	Perennial	Seed	March onwards	259
Scaevola crassifolia	Thick-leaved Fan Flower	Erect, medium shrub	Perennial	Seed	November onwards	424
Senecio lautus	Groundsel	Groundcover	Annual	Seed	September – November	1210
Spyridium globulosum	Basket Bush	Medium or tall shrub	Perennial	Seed	September onwards	605
Templetonia retusa	Cockies Tongue	Medium shrub	Perennial	Seed	August onwards	429

Additional species that may be considered for replanting at a later stage in sheltered locations on dunes that are well stabilised, with a high level of vegetation cover include:

Acacia lasiocarpa	Dune Moses	$303/kg
Acacia truncata		$330/kg
Anthocercis littorea	Fireweed	$682/kg
Callitris preissii	Rottnest Island Pine	$347/kg
Cassytha racemosa	Dodder	$759/kg
Diplolaena dampieri	Dampier's Rose	$402/kg
Eremophila glabra	Tar Bush	$319/kg
Exocarpus sparteus	Broom Bush	$209/kg
Melaleuca acerosa	Coastal Honey Myrtle	$385/kg
Melaleuca huegelii	Chenille Honey Myrtle	$330/kg
Melaleuca lanceolata	Rottnest Island Tea Tree	$215/kg
Santalum acuminatum	Sweet Quandong	$28/kg
Spyridium globulosum	Basket Bush	$605/kg
Templetonia retusa	Cockies Tongues	$429/kg

Some coastal dune plants have useful characteristics. Oma *et al.* (1992) give the example of *Acanthocarpus preissii*, a very prickly native species that can be planted along fences and pedestrian accessways to deter pedestrians from entering rehabilitating areas and other highly fragile areas.

Seed and propagule collection, processing, storage and germination requires basic training for participants, as well as the provision of appropriate plant collecting permits from CLM (formerly CALM) and approval from landowners and managers. APACE AID Inc could provide assistance with training courses. The aim of seed collection is to collect mature seed. Fire history will determine the availability of seed in a given reserve at a give time. The most productive times for seed collection are one to two years after fire for obligate seeders (plants that respond to fire by seeding) and just prior to fire for resprouters (plants with a lignotuber that respond to fire by resprouting). Some best practice seed collection techniques are outlined in Table 7.

Table 7: Best collection practices for collection of native seed

Source: South Metropolitan College of TAFE (nd)

BEST COLLECTION PRACTICES

DO NOT:

1. Damage the parent plant. If hand pulling of fruits is stripping bark, then cut with secateurs.
2. Collect more than 20% of the seed from each plant. Seed must be left for plant reproduction and as food for insects and animals.
3. Mix species in the same bag. This is for hygiene reasons and to ensure that seed is not contaminated with other species.
4. Collect if possible during wet or just after rain as the fruit is more likely to be attacked by fungi.
5. Store fruits in plastic bags as this will encourage fungal growth.

DO:

1. Collect from more than 10 plants of the same species over a distance of more than 100 metres to ensure that as much genetic diversity as possible is obtained.
2. Collect only mature seed.
3. Collect from the middle to upper branches if possible.
4. Collect from healthy plants.
5. Label every bag or envelope with:
   Date…
   Collector…
   Location…
   Species…
   Comments…

5.2.4 Recreational Use

Active recreation areas and other facilities that attract crowds should not be placed next to highly fragile areas. Carparks should be as close as possible to beaches and attractions (within constraints imposed by environment). In the City of Joondalup, these considerations have generally been taken into account with the design and placement of existing recreational facilities. The recommendation of additional recreation sites is beyond the scope of this report.

5.2.5 Protection of Areas Under Rehabilitation

Fencing excludes people from fragile and rehabilitating areas and guides them to their destination through environmentally suitable areas. Low post and rail fences present a psychological barrier, while farm-type fences consisting of posts and ringlock, or posts and wire mesh, present more of a physical barrier. Accessways to beach areas should be fenced on both sides with farm-type fences to discourage pedestrian traffic across dunes. Rehabilitating and fragile areas should be similarly fenced.

5.2.6 Public Information and Education

Signage in appropriate locations help inform visitors and the local community of the work which has been undertaken, the reasons why rehabilitation has been undertaken, and to encourage them to protect the area and use the facilities provided with care (Oma *et al.*,

1992). Signage denoting rehabilitation areas should not be overdone, and should represent the minimum wording, size and distribution required to effectively deter the public from entering rehabilitation areas (South Metropolitan College of TAFE, nd).

5.2.7 Monitoring and Maintenance

It is important to monitor any areas that have been rehabilitated to check for plant vigour, establishment and survival, the adequacy of temporary stabilising agents such as brush and mulch, and to ensure that people are using accessways rather than trampling vegetation, that signs have not been vandalised, and that the rehabilitated area will remain stable (Oma *et al*., 1992; South Metropolitan College of TAFE, nd). Rehabilitated areas should be maintained constantly, because even minor damage to dunes can rapidly develop into a major problem.

Monitoring should occur regularly, preferably on a monthly basis for the first year. Monitoring should be carried out on foot, or as part of ranger patrols in vehicles. Generally, at least 30% of the original budget for implementing rehabilitation works should be allocated to maintain the rehabilitated area in the first wet season (Oma *et al*., 1992). Up to 10% of the original budget may be required for future annual maintenance depending on the nature of the landforms, and coastal and use processes operating in the area (Oma *et al*., 1992).

5.3 Weed Control

Weed control is an important component of coastal management. Along many stretches of heavily populated coast, weed species, particularly on foredunes and mobile dunes, often outnumber native species. In these areas, exotic species that bind the sand together, such as *Pelargonium capitatum* (Rose Geranium) and *Tetragonia decumbens* (Sea Spinach) fulfil an important role in reducing erosion hazard. Weeds can also significantly increase fire hazard if large numbers of annual, grassy weeds are present in the area. Fires pose a threat to the integrity of coastal vegetation and can quickly result in dune erosion, as well as threatening property such as fencelines. There are a number of strategies available that can reduce the abundance of weeds along the foreshore, whilst retaining the integrity of the dunes, encouraging natural regeneration, reducing fire hazard, and decreasing dependence on chemical control of weeds. These strategies are detailed in sections 5.3.3 to 5.3.8 and in Appendix Three.

5.3.1 Impact of Environmental Weeds

Environmental weeds are plants that establish themselves in natural ecosystems and modify natural processes, resulting in the decline of the communities they invade. Impacts on ecosystem function by environmental weeds include:

- resource competition, as weeds often outcompete native species;
- prevention of seedling recruitment of native species;
- alteration to geomorphological processes, such as increased erosion;
- changes to soil nutrient status;
- alteration of fire regime, usually through increased fire frequency;
- changes to the abundance of indigenous fauna due to less diverse habitat;
- loss of genetic diversity;
- loss of species diversity; and
- changes to the structure of vegetation communities, often by the removal of the shrub layer or native ground covers.

5.3.2 Weed Management Considerations for Coastal Dunes

Particular attention is required for weed control programmes in coastal dune areas. In some areas, priority weeds are the dominant component of the flora and play an important role in preventing dune erosion. *Arctotheca populifolia*, *Cakile maritima* and *Tetragonia decumbens* are all *Moderate* rated weeds, and *Trachyandra divaricata* has a *Mild* rating, and should only be controlled where there is no danger of a blow-out occurring. *Tetragonia decumbens* should not be confused with native species of *Tetragonia*, such as *T. implexicoma*. *Pelargonium capitatum* is a *High* rated weed and should be controlled, preferably with a herbicide as the dead plant material will help to hold the soil together and reduce the likelihood of erosion. On west-facing dunes (where wind erosion is likely) with a high proportion of these species, it will be prudent to immediately plant native dune-colonising species following the removal of weed species, and to ensure that large bare patches of sand are not created by weeding. Incremental weed control in these areas will be vital to ensure that erosion does not occur.

5.3.3 Weed Control Methods

Control options for environmental weeds include:

- Controlling ecosystem degradation processes;
- Herbicides;
- Manual control;
- Assisted natural regeneration; and
- Fire management.

Controlling degradation processes that increase ecosystem vulnerability to weeds is often the most effective way to control weeds in the long term, and in the case of Joondalup, this will include restricting access and public education. The control methods described in the sections below are herbicide control, manual control and assisted natural regeneration.

Manual Control

Manual control refers to the physical removal of the weed by mechanical or human effort. This includes hand weeding, pulling and digging or grubbing out and relates to small infestations of weeds (Dixon and Keighery, 1995).

Manual control is often the most expensive form of weed removal but it is the most appropriate method in circumstances where there are small infestations in largely natural bush areas. It is particularly valuable for small infestations, where chemical control is inappropriate and resource requirements are not too onerous. Manual control needs to be carefully managed in order to avoid gross soil disturbance that can lead to weed replacement. When undertaking manual weed control, the Bradley (1971, 1988) method should be used (Appendix Three) and revegetation or assisted natural regeneration should be undertaken in conjunction with weed removal. Hand-pulling of weeds may be as time-efficient as spraying in certain situations – for example, where low numbers exist in a localised, well-vegetated area of bush – and should be given priority over herbicide spraying.

Assisted Natural Regeneration

Assisted natural regeneration (ANR) may be appropriate in some areas of the Joondalup foreshore. This method is based on the Bradley method of bush regeneration (Appendix Three) and was developed for bushland areas. ANR may be used where a remnant of vegetation exists in *Fair – Good* to *Very Good – Excellent* condition and retains its natural regenerative capacity. It can also be used once a reconstructed community regains its natural regenerative capacity. Assisted natural regeneration involves removing weeds and disturbance factors from the environment. ANR should commence in areas of the best condition, consolidating these areas, before gradually progressing to areas in worse condition.

Herbicide Control

Herbicide application is often the most cost effective method for the control of weeds. A wide range of herbicides are available for weed control. It is important that herbicides should always be used strictly in accordance with directions on the label and their application must be undertaken by personnel trained and licenced in the use of herbicide chemicals in public open spaces (ie, commercial operators).

Dixon and Keighery (1995) identified three methods of herbicide control, as follows:

- Herbicide Wipe, Stem Injection and Cut Stump Application
  - Herbicide Wipe – wipe herbicide onto part of the plant (for example a leaf/leaves) using a weeding wand, wick applicator (rope), waterproof (pesticide resistant) glove or modified hand sprayer;
  - Stem Injection – use a small axle to make cuts at 8 cm intervals at a 45^{o} angle and 4-5 cm long to penetrate the sapwood beneath the bark, or drill at 45^{o} angle with holes 5 cm apart. If the plant is multi-stemmed, treat all stems at chest height. Use a special injector calibrated to deliver the right amount or use a syringe; and
  - Cut Stump Application – when the plant is actively growing, cut the stump almost to ground level and apply the herbicide immediately using a paint brush.
- Herbicide Spot Spraying
  - When spot spraying, avoid spraying non-target species unless using selective herbicides such as Fusilade®. Special shields can be purchased or, if necessary, made for spraying close to non-target species.
- Herbicide Blanket Spraying
  - When blanket spraying, spray over large area using boom spray or similar, when the plant is actively growing (early June to no later than mid-August or when specified).

Two of the major herbicides recommended for use are glyphosate (Roundup®) and fluazifop (Fusilade®). Glyphosate is a systematic non-selective herbicide, which is useful for controlling most weeds, particularly bulbous species. Glyphosate should not be blanket sprayed in areas containing native species, as it will also kill them. Fluazifop is a selective herbicide that is effective on most grassy weeds. Fluazifop does not affect non-grass native species. A dye should be added to the herbicide to mark areas sprayed.

5.3.4 Guiding Principles for Weed Control

When undertaking weed control programmes, the primary guiding principle is to work from areas in the best condition to those in the worst condition, and all works should be undertaken in conjunction with a restoration strategy (Bradley, 1971; Bradley, 1988; Buchanan, 1989). A bushland condition map can be referred to as a guide for priority weed control as follows:

1. Populations occurring in *Very Good - Excellent* condition bushland areas (green areas) should be treated first;
2. Those populations occurring in *Fair - Good* condition bushland areas (blue areas) should be treated next, in the order of:
   - Blue within green areas
   - Blue bordering green areas
3. Populations occurring in *Poor* condition bushland areas (orange areas) should be treated last, in the order of:
   - Orange within green or blue areas
   - Orange bordering green or blue areas.

Using bushland condition as a criteria for determining weed control priorities ensures that:

- *Very Good - Excellent* condition bushland is maintained;
- *Fair - Good* condition bushland is enhanced, moved closer to being in *Very Good - Excellent* condition, and prevented from deteriorating to *Poor* condition bushland; and
- *Poor* condition bushland is enhanced, moved closer to being in *Fair - Good* or *Very Good - Excellent* condition, and prevented from deteriorating to *Very Poor* condition bushland.

The *Very Poor* condition areas are generally not suitable for targeted weed control. Instead, weeds in these areas should be addressed within the context of a comprehensive restoration plan.

5.3.5 Approaches to Weed Control

Approaches to the control of priority weeds can be categorised into:

- Species-led control;
- Site-led control;
- Resource-led control;
- Cause-led control; and
- Threatened species and communities led control (CALM, 1999).

Only the first three approaches to control will be described below. Cause-led control is a preventative measure which aims to reduce the impact of factors that aid the spread and establishment of weeds. There are no threatened ecological communities identified from the foreshore, although several Priority 2 and 3 flora species occur.

Species-led Control

Species-led control is a proactive strategy to prevent introduction, establishment, survival, reproduction and dispersal of an emerging weed before it becomes a major problem along the foreshore

Generally, it is recommended that species-led control be undertaken prior to site-led control. Weed species should be tackled on a weed by weed basis, and can be placed in this category if they:

- Have small populations;
- Are relatively easy to remove;
- Have a high potential to spread and therefore become a problem in the future; and
- Are located in areas that will not be continually reinfested from the soil weed seed bank or from surrounding areas.

Site-Led Control

Site-led control focuses on identifying areas that require weed control to maintain their ecological and commercial values. Site-led control is appropriate for most of the Joondalup coast. Generally, it is recommended that site-led control be undertaken after control of weeds recommended for species-led control. Weed species can be placed in this category if they:

- have wide-spread and well-established populations;
- require concentrated and/or long-term efforts to remove; and
- are highly detrimental to ecological functions of bushland if left unchecked.

Resource-Led Control

Resource-based weed control is recommended where a particular species is known to be within a defined area, and thereby providing a focus for community projects. A human resources led approach matches volunteer and professional labour to the best possible weed control outcomes. For example, volunteers may be best suited to target small populations of highly visible weeds which are readily removed by simple manual or chemical methods and are ideal for essential follow up and monitoring. Professionals may be best used where spraying or machinery is required or where a concentrated effort is required.

5.3.6 Control of non-Priority Weed Species

Weed species which were not included in the list of priority species should not be excluded from control activities on that basis. These species should be included in any weed control programme as species which could be controlled if resources allow, but which are not of as high a priority for control. As weed control of priority species progresses, other weed species which previously may not have been rated as highly, may become more important. Therefore, it is important to keep weed control programmes flexible and updated according to monitoring data, to ensure that as bushland condition changes and weed species dominance changes, the control activities are adjusted accordingly.

The priority status of individual weed species should be used as a basis for its control, along with factors such as its abundance and distribution. For example, weed species with a *Moderate* or *Mild* priority for control, but which has a limited distribution should be controlled if resources allow, rather than left to spread and become a bigger problem. In general, those species with a *High* priority rating should be tackled first, but the situation at each site needs to be assessed in context with which other species are present and what resources are available.

5.3.7 Post-fire Weed Management

Following fire, weed species have an opportunity to increase in density and abundance. Ongoing weed management must also include post-fire weed management to break the fire-weed cycle. Post-fire weed control requires diligence and a high degree of care from operators. Training should be provided to staff carrying out these duties, or specialist bush regenerators employed in order to achieve the desired outcome without compromising the ability of the bushland to regenerate. The post-fire environment is susceptible to further damage, and weed control works should be undertaken at a time that will give the vegetation the greatest chance of successful regeneration. Implementation of weed control in the post-fire environment should incorporate the following factors:

- If the fire occurs in early summer, weed control should be carried out three months after a fire;
- With later summer fires, inspections should be carried out at four, six and eight weeks after the fire in order to assess the most appropriate interval at which to carry out weed control. The interval will vary according to weather;

- The affected area should be monitored and, if necessary, a follow-up treatment should be applied; and
- As with all weed control programmes in natural areas, it should be linked to a regeneration programme. Assessment of individual situations is required to determine the needs for each site.

5.3.8 Monitoring and Evaluation

Monitoring and evaluation are key actions that need to be undertaken in weed management to measure the success of strategies advocated in this report. As part of objectively assessing the success of a weed control strategy, performance indicators need to be developed. This will not only contribute to its accountability where public funds are involved, but also provide a mechanism for modifying the strategy and maintaining its flexibility.

When monitoring site specific projects, the following strategies are suggested:

- Establish monitoring quadrats in areas subject to weed control programmes to record the effectiveness of control methods;
- For species-led control – monitor effectiveness of control of discrete weed populations or patches, including presence or absence, and, if present, the degree of new infestation;
- For site-led control – establish monitoring quadrats and survey and record annually;
- For both control methods – monitor the effectiveness of different control methods used (manual vs. chemical control; spot spray vs. blanket spray; contractor vs. community control). The use of photographs from set points enhances this process; and
- Monitor quadrats for establishment of new weed species.

Performance Criteria

In order to determine the effectiveness of any weed control programme, there needs to be a method of determining success and ongoing progress. The following gives examples of the factors that could be assessed:

- Removal of a set number of priority weed species (say four or five) from the targeted areas over the next five years;
- Reduction in the area of priority weed infestations by 5% over 5 years; and
- Reduction in the total number of weed species present by 5% over 5 years.

5.4 Fire Management

5.4.1 General Impacts of Fires on the Biological Environment

Fires can impact upon the natural vegetation in a number of ways including:

- Promotion of weed growth;
- Alteration of species composition;
- Threat to the viability of rare, endangered or geographically restricted species; and
- Threat to the viability of obligate seeder species (which are typically more sensitive to fire than lignotuberous species that can resprout following fire).

Fires at intervals more frequent than the inherent regenerative capacity of the vegetation can promote the spread of exotic weeds by creating the required conditions, including:

- Increased light penetration through burnt-out overstorey;
- Reduced competition from native perennial species; and
- Increased availability of nutrients.

Increased weed growth, particularly annual grassy weeds, greatly increases the fire risk in a number of interrelated ways, including:

- Forming a fine-textured fuel which is highly flammable;
- Producing a high fuel load annually depending on climate and growth rate. Native plants take much longer to reach the same fuel levels;
- Forming a continuous fuel bed, permitting a fire to spread quickly. Native plants usually have gaps between them which act to slow down the spread of fire; and
- Creating a very hot fire at ground level.

This situation leads to a cycle of increased weed growth leading to increased fire risk and thus increased fire intensity and frequency, which in turn lead to increased weed growth. The effect this situation has on natural communities is profound and can quickly lead to a greatly reduced diversity of flora and fauna.

Fires are of particular concern on coastal dunes if the ground cover and vegetation are consumed, as areas of bare sand can be easily eroded, especially if combined with inappropriate human or animal access, or weather conditions such as high wind or heavy rain. Areas that have been generally regenerate naturally in the following season, but replanting, reseeding and rebrushing may be required if regeneration does not occur after the first wet season. Brushing may also be required to protect the sandy surface, helping plants to germinate and grow (Oma *et al*., 1992).

5.4.2 Fire History and Ignition Risk

Fire history has a major role to play in the determination of fuel condition and quantity. The recording of accurate fire histories is an essential component of fire management planning. This involves the recording, preferably on GIS, of the following factors:

- Location of ignition;
- Cause of ignition (if known);
- Season/date and time of ignition;
- Fire perimeter; and
- Fire intensity and locations of unburnt refugia within the perimeter. Fire intensity will vary within the fire perimeter and these variations should be recorded, possibly from aerial photos taken soon after the fire

Fire histories built up in this way will provide a firm basis for identifying areas at high risk because of frequent burning. Time since last burn is of less importance in areas where grassy understorey is present as this returns to pre-fire fuel loads rapidly. Mapping of fire histories will also allow identification of areas that have not been burnt for many years, as these are also an important conservation value.

By concentrating ranger patrols at times when fire ignition risk is highest, a proportion of deliberately lit fires could be prevented. Fire and Rescue Service (FRS) incident statistics from 1996/97 and 1997/98 indicate that ignition of grass, scrub, bush and rubbish (GSBR fires) peak in December and January (FRS, 1997; FRS, 1998). Ignitions are lower in February and March, although fuel moisture levels are lowest at these times of the year. December and January correspond to school holidays. Anecdotal information suggests that during the summer school holidays there are two peaks in fire ignition, with the first three to five days after holidays commence, and the second one week before the holidays end.

There are also variations in the pattern of ignitions over a 24 hour period. Based on FRS incident statistics, the period of lowest frequency of ignitions is generally between 3am and 8am. The period between 1pm and 12am records the highest frequency of ignitions, with distinct peaks that correspond to human activities. In 1996/97, two peaks in ignition were recorded, with one between 2pm and 6pm (corresponding to the end of the school day and the last few hours of the working day) and the second between 7pm and 12pm (corresponding to the after-dinner leisure period). In 1997/98, three peaks in ignition were recorded, with the highest frequency between 2pm and 5pm, and other peaks between 8pm and 9pm, and at 11pm. Again, these peaks correspond with the after school period and the after dinner leisure period.

5.4.3 Strategy

Fire management strategies generally have four core elements as follows:

- Hazard reduction;
- Fire suppression;
- Public education; and
- Post-fire recovery and incident analysis.

Although beyond the scope of this project to recommend detailed fire management strategies, these four core elements are elaborated upon below.

Hazard Reduction

Hazard reduction involves actively removing the incidence of fire ignition and reducing fuel levels. Ignition reduction involves removing or reducing the causes of fires within the park. By far the greatest cause of fires in urban bushland is arson. Unfortunately, arson is difficult to police and offenders are rarely caught. A community education programme highlighting the destructive nature of bushfires may help reduce the incidence of arson within the park.

Bushfires can be accidentally lit, with common causes including escapes from burning rubbish, barbeques and campfires, cigarette butts, escapes from controlled burns, children playing with matches, powerlines and the operation of plant and machinery. Fires started by lightning strikes are the only natural cause of bushfires. A community education programme highlighting activities that could lead to accidentally lit bushfires could reduce the incidence of bushfires, especially near areas where the number of visitors is greatest. All barbeques in picnic areas should be gas or electric.

Fuel reduction involves reducing fuel levels to a point where any potential fire can be controlled by fire fighting crews on a normal summers day (Wycherley and Robley, 1983).

The appropriate method of fuel reduction in coastal areas is through weed control, especially on road verges, and next to pathways through the area. Road verges are one of the most common sites of ignition. Prescribed burning is not appropriate for fuel reduction in coastal areas.

Another method of fuel reduction is the construction of low fuel zones. Dual use paths and roads act as firebreaks along the Joondalup coast. The surface of firebreaks should be fire retardant, and firebreaks should be 2-3 metres wide. In coastal areas, fire retardant surfaces could include succulent groundcovers, such as *Carpobrotus virescens*, in addition to the more standard surfaces of concrete, crushed limestone or sand.

Fire Suppression

Fire suppression involves fire-fighting application once a fire has started and taken hold. Fire suppression can only be effective if fires are detected quickly and fire fighters can respond and access the fire and contain it before it becomes uncontrollable. A "Fire Watch" programme can be of great assistance in alerting fire control authority to fires.

Fire suppression requires trained, experienced staff and volunteers, with suitable equipment, who are available within a short response time to fight fires. Fire suppression activities have the potential to degrade the environment through the unplanned construction of firebreaks and tracks, which lead to erosion, destruction of vegetation, and the proliferation of tracks. Fire suppression cannot be relied upon as the main fire control technique. Fire suppression must be integrated with effective ignition and fuel reduction programmes.

Public Education

A community education programme should be developed for the foreshore which highlights the dangers of wildfires to human life and property, and the destructive cumulative effects of frequent fire on flora and fauna. Education should focus on the risk of accidental fire lighting and the need for the public to be vigilant against arsonists. Education programmes should also include methods of preventing wildfire, controlling their spread and ensuring human safety in the event of a major fire along the foreshore.

Post-fire Recovery and Incident Analysis

Coastal dunes are in a highly sensitive condition following fire. Most of the fine material is scorched or burnt, so that photosynthetic processes are reduced or cease. This affects food webs which shift, at least temporarily, from a herbivore base to a scavenger base. The sand is left bare and sensitive to erosive processes, such as vehicle and foot movements, heavy summer rain and wind. Some of the fauna will have perished in the fire, others will have sought unburnt refuges, placing greater strain on the resources of unburnt areas. Regrowth and germinating seedlings will be subject to intense grazing pressure, not only from vertebrates (especially rabbits), but also from invertebrates such as crickets.

Following a fire, an initial assessment should be undertaken of the potential for erosion of bare ground. Erosion control measures should be implemented as soon as possible after the fire. Access to any burnt areas should be limited to management purposes only for the first six to twelve months. In areas high pedestrian use, foot access should be limited to limestone-stabilised tracks or other firm surfaces. Signage can be used to encourage

sensible behaviour, as well as to explain the regenerative processes that can be observed following fire.

Seed germination and resprouting in vegetation should be monitored for a year following fire. Although recovery should be adequate if grazing and weed control measures are implemented, additional direct seeding and tubestock replanting may need to be considered if germination success is low.

Fire fighting operations have the potential to cause mechanical damage through trampling of vegetation, water erosion and small scale clearing. This cannot be entirely avoided, though should be minimised where possible through appropriate training within the fire-fighting authorities. Trained bush regenerators should carry out reparation of mechanical damage.

Post-fire incident analysis is an important facet of fire management which enables fire fighters and fire control authorities to review procedures, strategies and tactics and revise them in light of experience. All fires that occur in an area should be recorded. Information that should be compiled includes the date, season, time, cause of ignition, intensity and extent of the fire, fire control methods used and damage caused by the fire. This information can be used for long-term fire management planning.

5.5 Disease Management

Although not yet raised as a concern for the Joondalup foreshore, mention should be made of *Armillaria luteobalbina* (also known as honey fungus), which is a mushroom-producing fungus that is native to Western Australia and commonly occurs in the south-west of the state. Unlike the plant pathogen *Phytophthora cinnamomi* that results in dieback disease, *A. luteobalbina* is not restricted to certain soil types. Dieback disease would not occur on the Joondalup foreshore due to the soil types present.

Armillaria luteobalbina appears as a golden yellow fruiting body at the base of tree stumps around June or July. The infection is caused by the aerial dispersion of spores, or through mycelium in root systems. Infection entry points for the spores may be provided by wounds caused by fire, broken limbs and insect damage. *A. luteobalbina* can kill many coastal species and in severe cases can cause sand dunes to erode. As *A. luteobalbina* is not purely a soil-borne pathogen, it is impossible to contain the pathogen by utilising current hygiene practices. There is no known cure for the disease. The best strategy for minimising the impact of the fungus would be to reduce plant stress to enable plants to resist and combat fungal attack, and to avoid spreading infected plant material during any dune stabilisation operations and other earth-moving activities.

5.6 Feral Animal Control

The feral animal species of most concern along the Joondalup coast is the European Rabbit (*Oryctolagus cuniculus*). This species is abundant in the coastal heath near Burns Beach, and presents a significant threat to the germination of seedlings, particularly if a fire were to occur in the area. Rabbit control would need to be undertaken if a fire occurred, or prior to seeding and planting programmes if they are planned in this area.

The anti-coagulant Pindone has been used for rabbit control in other areas, but native animals are highly susceptible to Pindone poisoning. The presence of native mammals in the Burns Beach heath area is not known, so that the potential adverse impacts of baiting can not yet be quantified.

6.1 Determination of Management Zones

Four management zones have been determined for the vegetation of the coastal foreshore of the City of Joondalup (Figures 5 and 6) in order to guide management and maintenance priorities:

- Conservation;
- Low Intensity Recreation;
- Medium Intensity Recreation; and
- High Intensity Recreation.

Areas proposed for conservation were determined based on the ecological and landform values of the area, independently of the level of public use or land uses present. The three recreation zones were determined based on the existing levels of public use and facilities present, and the sustainability of each level of use relative to the landform and ecology of each area. All of the conservation areas fall within the low public use zone. Low intensity passive recreation, if properly managed, is deemed to be compatible with meeting the requirement for preservation of areas with high conservation value. As such, the low intensity passive recreation zone overlaps with the conservation zone.

6.1.1 Levels of Public Use

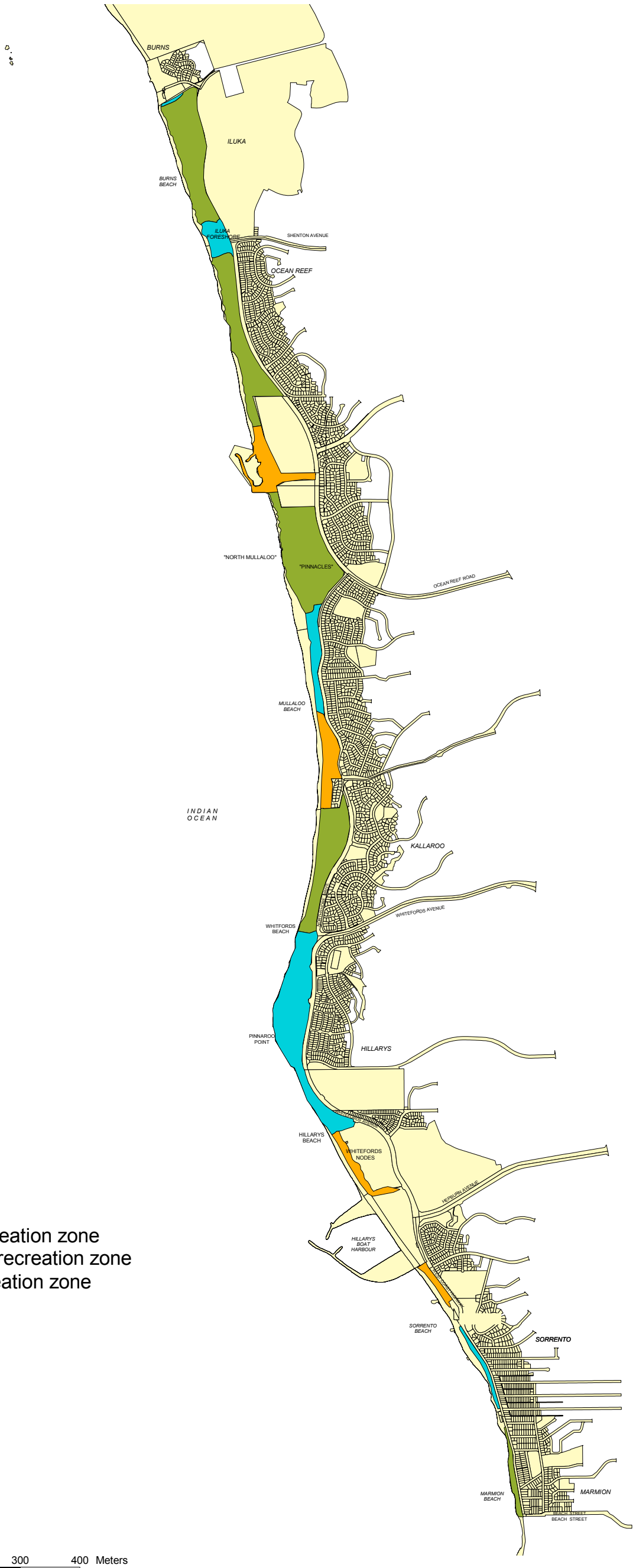
One of the objectives of this project was to identify existing areas of high, medium and low levels of public recreational use. Information on the level of use was gained from:

- The Recreation Officer at the City of Joondalup;
- The results of a 1999 survey of beach use using aerial photography conducted by Coast*Wise* (1999) (Figure 7);
- The level of access determined by car parks, roads and dual use paths;
- Proximity to recreational facilities and residential areas;
- Reference to existing reports; and
- Observations during the surveying of bushland condition.

The zones of public use of varying intensity are shown in Figure 6. According to both the Recreation Officer and the results of the 1999 survey (Coast*Wise*, 1999), the highest intensity use occurs at Mullaloo, Hillarys and Sorrento.

• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL CONSULTANTS
9 Stirling Highway North Fremantle Western Australia 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

FIGURE 5: Conservation Zones and Priority Rehabilitation Areas for Coastal Vegetation of the City of Joondalup

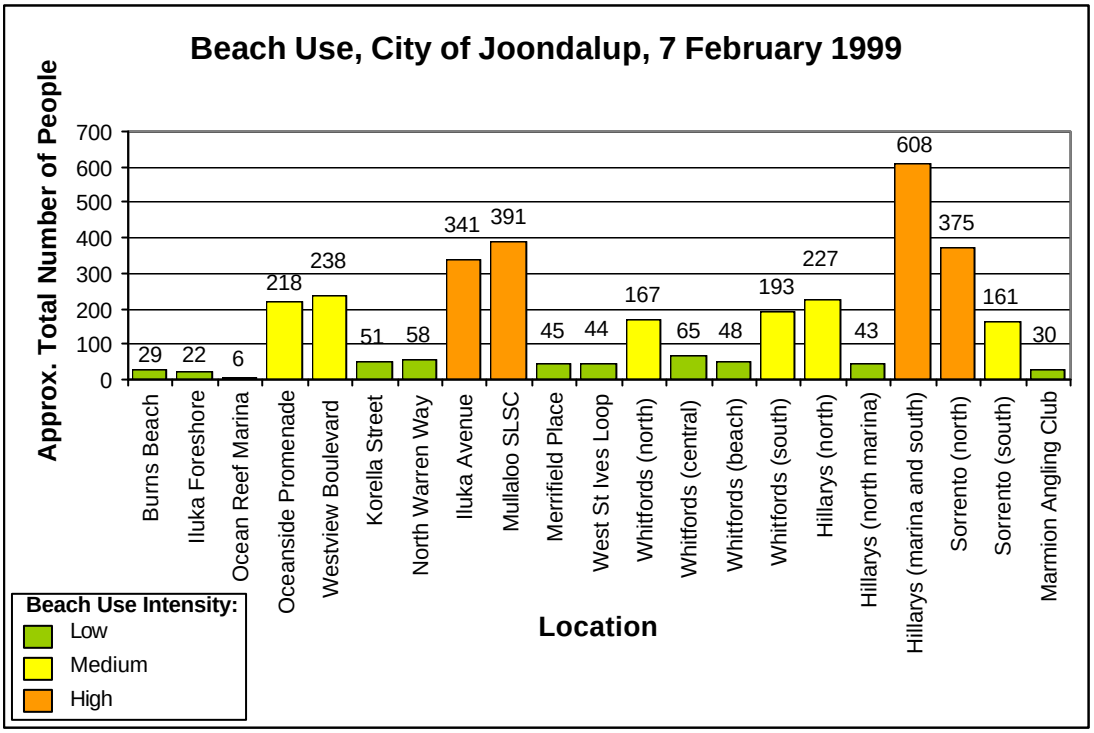


• E C O S C A P E •
ECOSCAPE (AUSTRALIA) PTY LTD ABN 70 070 128 675
LANDSCAPE ECOLOGISTS ENVIRONMENTAL CONSULTANTS
9 Stirling Highway North Fremantle Western Australia 6159
Telephone (08) 9430 8955 • Facsimile (08) 9430 8977
email: ecoscape@iinet.net.au

FIGURE 6: Low, Medium and High Intensity Recreation Management Zones

Figure 7: Detailed assessment of beach use on the City of Joondalup coast, 7 February 1999.

Total number of people was estimated from aerial photographs and includes people on the beach and in the water. Note that the totals are approximations only, due to some difficulties distinguishing people under umbrellas, on dark towels, and children. A total of 3,379 people were counted on beaches in the City of Joondalup, with 3,314 cars in neighbouring carparks. Source: Coast*Wise* (1999).



6.1.2 Conservation and Priority Rehabilitation Areas

Areas where conservation should be the primary objective were determined by reference to existing literature on the conservation values of the coast and the results of the bushland condition survey, and included areas identified as conservation zones in existing management plans (Figure 5). The extent of the conservation zone proposed for this study is significantly greater than that proposed in previous management plans, largely because regeneration of vegetation has improved the condition of some areas, notably the Ocean Reef and North Mullaloo areas.

Rehabilitation priority areas were also identified in areas either within or adjacent to the conservation zones. Rehabilitation of these areas would enhance the integrity of the conservation zones. Further detail on the order in which restoration programmes should be planned is given later in this section.

6.2 Description of Management Zones

6.2.1 Conservation Zone

The primary objective of this zone is to provide for the protection of the environment, landforms, significant fauna habitat and important vegetation communities while allowing low intensity public access to areas that are of significant environmental value.

This zone should provide for passive recreational uses, provided they are consistent with the primary conservation objective. Access should be defined within dual-use pathways (which also act as firebreaks) and look-out points in order to minimise erosion, weed invasion and fire risk. Erection of fencing between pathways and vegetation, and between the beach and foredunes, may be necessary in areas where significant degradation has occurred adjacent to the pathway or beach front, particularly in areas where people often walk across dune vegetation or cliff tops.

The designated conservation areas include:

- Coastal heath and low woodland from Burns Beach to Ocean Reef, extending from the cliff edges inland. Designated for conservation due to the generally excellent condition of the coastal heath, the large relative width of the coastal reserve in this area, and the presence of the "best remaining example of a limestone ridge forming cliffs in the northern coastal metropolitan area. The coastal heath is of value in itself, as a wildlife corridor, and could also form significant fauna habitat, particularly for nesting birds and reptiles. Coastal heath in the far north of the study area, from Burns Beach to the Iluka Foreshore area, was previously recommended for conservation, and is considered to be of the highest conservation value in the area from Burns Beach to Ocean Reef;
- Heathland and *Acacia* woodland in the North Mullaloo area, including the "Little Desert" area and coastal cliffs south of Ocean Reef Harbour. Designated for conservation for the variation in landforms, including high dunes, coastal cliffs, and the Little Desert area, which itself includes an Aboriginal artefact site, and for the generally excellent condition of the dune vegetation, which has regenerated to cover a number of old tracks and cleared areas. The Little Desert area was previously recommended for conservation (Woods, 1984a; Tract and Kinhill Engineers, 1995); and
- The high dunes at the northern end of Whitfords Beach. Included due to the landforms, including high dunes and the steep dune front at the beach, and for the generally excellent condition of the vegetation.

Another area that could be considered for inclusion within the conservation zone is the vegetation within the coastal portion of the Whitfords Nodes, at the southern end of Hillarys Beach. Although this area is relatively narrow and has suffered from disturbance such as fire and weed invasion, the low woodland vegetation on the leeward side of the foredune includes species that are uncommon in such close proximity to the coast in the Perth metropolitan area. These species include Rottnest Island Pine (*Callitris preissii*), Quandong (*Santalum acuminatum*), Tuart (*Eucalyptus gomphocephala*), and Moonah (*Melaleuca lanceolata*). In many parts of Perth, low woodland in coastal areas has been replaced by *Acacia* shrubland due to increased fire frequency following European settlement. Existing management plans for Hillarys Beach and the Whitfords Nodes does not explicitly mention the vegetation of this area, but refer to revegetation efforts that have been undertaken in the area. It is not clear whether these species have been planted in this area or occur naturally.

Interpretive signage in this area, drawing attention to some of these species and the change in the composition of Perth's coastal vegetation over the last 150 years, would be a useful educational tool.

Although in relative terms, the number of users of most of the conservation zone is low (due largely to the fact that existing access paths remain on the periphery of the zone rather than through the centre of conservation areas) there is still the potential for significant environmental degradation if use of the area is not carefully managed. The conservation zone contains exposed, unstable limestone cliffs with low coastal heath easily damaged by trampling, and sand dunes that can be easily eroded if the vegetation cover is damaged or removed. There are a number of degraded and eroded areas within the conservation zone that should be rehabilitated. The coastal heath and shrub in the Burns Beach area would suffer significant environmental damage if a fire burnt through the area, as previously mentioned. At present, there is no substantial east-west firebreak through the heathland of highest conservation significance in this area.

6.2.2 Low Intensity Passive Recreation Zone

The objective for this zone is to provide facilities to cater for low levels of public use and recreation, whilst maintaining the conservation value of the area. Low intensity passive recreation areas are generally those areas where:

- Access is almost entirely by either pedestrians or cyclists, along pathways or beach front distant from carparks and other facilities;
- There is a low demand for access to the area;
- Existing recreational activities are passive and consist chiefly of walking, jogging, cycling, swimming and fishing;
- Existing recreational activities are generally not concentrated at nodes, but rather are spread relatively evenly at low density along linear, accessible stretches; and
- Vehicular access to the beach is not permitted except by authorised vehicles.

6.2.3 Medium Intensity Passive Recreation Zone

The objective for this zone is to provide facilities to cater for medium levels of public use and recreation, whilst maintaining the integrity of the vegetation and landforms of the area. Medium intensity passive recreation areas are generally those areas where:

- Access is largely by pedestrians or cyclists, along pathways or beach front more than a short walk (ie at least a few minutes) from large carparks and other major recreational infrastructure, or a short walk from small carparks;
- There is a moderate demand for access to the area;
- Existing recreational activities include passive recreation and some more specialised activities, including walking, jogging, cycling, swimming, fishing, animal exercising, boating, boat launching, sailing and windsurfing; and
- Some of the more active recreational activities can be localised to specific areas away from the general beach-going public, such as zones for waterskiing and windsurfing.

6.2.4 High Intensity Passive Recreation Zone

The objective of the high intensity passive recreation zone is to provide facilities and management for high levels of passive recreational activities, while implementing measures that will reduce the impact of these activities on the biophysical environment. High intensity passive recreation areas are generally those areas where:

- Popular swimming beaches are located (such as Mullaloo Beach and Sorrento Beach), which are patrolled by surf lifesavers and have associated infrastructure, such as large carparks, grassed areas, buildings, toilet and shower blocks and a large number of access ways across the dunes to reach the beach;
- Boat launching facilities (other than beach launching) are located (Ocean Reef Boat Harbour);
- A high proportion of visitors arrive by car and walk a short distance from relatively large carparks to the site of recreation, which is generally the beach;
- There is a high demand for access to the area;
- High intensity use is often concentrated in time and space, with peak usage during summer, and at nodes surrounding swimming beaches and associated infrastructure;
- There is a moderate demand for access to the area; and
- Existing recreational activities are generally passive and include swimming, walking, jogging and cycling. Other uses in this zone may require specialist infrastructure, such as boat launching ramps.

Many of the areas of high intensity use consist of a relatively narrow strip of dune vegetation, which is often degraded by significant weed invasion, vegetation disturbance, erosion, the effects of frequent, low intensity fire, and the effects of human traffic across the dune vegetation (rather than using defined access paths).

6.3 Plan for Management

6.3.1 Dune Restoration

Dune rehabilitation is considered to be of highest priority for areas of bare sand within the conservation zone, particularly those areas that are at risk of exacerbated erosion from wind and waves (beach front dune blowouts). These areas have been denoted as priority rehabilitation areas. Considering the length of the Joondalup coastline, there are relatively few areas where major dune rehabilitation is required due to erosion. Dune rehabilitation and restoration should be carried out in conjunction with a systematic weed control programme (described below).

Sand trapping fences, or the lower cost alternative of brush layering, may be appropriate for rebuilding dune blowouts in the Whitfords area, as this section of the coastline is accreting. Rebuilding the dune blowouts to the height of surrounding dunes will be a lengthy process, dune to the steepness and height of the dunes. At the initial stage, placing fences or brush across dune blowouts would at least reduce further human access to these areas, reducing the incidence of disturbance. Planning and placement of these structures should occur in the near future, in order to prevent the blow outs from increasing in size.

Many of the areas where restoration has already taken place are presently in excellent condition, with the mulch cover remaining intact, few weeds, and plants growing. The use of tritter, or guillotined brush, is recommended for trial in areas exposed to high winds or sandblasting.

Similarly to weed control, the priorities for dune restoration and planting programmes should be set according to the bushland condition maps. In general, seeding, planting and brush or mulching will not be required in areas of *Very Good – Excellent* condition. Restoration efforts should commence in areas of *Fair – Good* condition within green areas, with the aim of improving the condition of these areas to *Very Good – Excellent* in the long term. Efforts should move next to areas of *Fair – Good* condition bordering green areas, then to *Poor* areas within *Fair – Good* or *Very Good – Excellent* condition, then to *Poor* areas bordering *Fair – Good* or *Very Good – Excellent* condition, and finally to other *Poor* areas. However, given the dynamic nature of coastal areas, and the high potential for further damage to *Poor* and *Very Poor* condition areas, action should be taken as soon as possible to prevent further deterioration, and to prevent human access into these areas. This will generally involve erection of fences where these are not already present, or placement of temporary stabilisers such as brush, mulch and tritter on exposed surfaces.

Species used for dune planting should all be native species local to the area being replanted. Community volunteers could be involved in planting of native species. Seed and propagule collection could be undertaken along the foreshore to provide parent material, according to the principles outlined in the previous section. Consideration could be given to establishing a nursery or herbarium in which plants and seeds can be germinated and stored, providing a valuable resource and focus for community activities. Community volunteers could be involved in this process, given proper training and guidance.

All areas where restoration has been undertaken should be fenced to prevent human access into the area. In many instances, coastal vegetation can regenerate successfully by reducing disturbance, through fencing and other management techniques. The area of coastal heath adjacent to the extension to Ocean Reef Drive should be fenced before road construction commences.

6.3.2 Weed Control

Weed control activities should be guided by the management zones, and by bushland condition and weed mapping. Weed control should always be undertaken in conjunction with assisted natural regeneration or other dune revegetation techniques such as seeding, planting and mulching. Weed control in conservation zones is considered to be of higher priority than weed control in areas that are not part of the conservation zones. The order in which weed control activities should be undertaken is as follows:

1. Populations occurring in conservation zones in *Very Good - Excellent* condition bushland areas (green areas) should be treated first;
2. Those populations occurring in conservation zones in *Fair - Good* condition bushland areas (blue areas) should be treated next, in the order of:
   - Blue within green areas
   - Blue bordering green areas

3. Populations occurring in conservation zones in *Poor* condition bushland areas (orange areas) should be treated next, in the order of:
   - Orange within green or blue areas
   - Orange bordering green or blue areas
4. Populations occurring outside conservation zones in *Very Good - Excellent* condition bushland areas (green areas) should be treated next;
5. Those populations occurring outside conservation zones in *Fair - Good* condition bushland areas (blue areas) should be treated next, in the order of:
   - Blue within green areas
   - Blue bordering green areas
6. Populations occurring outside conservation zones in *Poor* condition bushland areas (orange areas) should be treated last, in the order of:
   - Orange within green or blue areas
   - Orange bordering green or blue areas.

Weed populations in *Very Poor* condition areas are generally not suitable for targeted weed control efforts, and should be controlled as part of a comprehensive rehabilitation plan.

Some of the areas where weed control has been undertaken in the past include sections of the dunes at Sorrento, where community volunteers have removed large areas of *Pelargonium capitatum*. While these efforts are appreciated, it is recommended that future weed control efforts be refocussed on areas of the dunes that are already in relatively good condition, so that the condition of these areas can be improved before tackling more difficult areas. As well as increasing the integrity of the dunes in this way, the results of community and the city's efforts can be seen more readily, with less frustration encountered due to continual reinvasion from weeds in surrounding areas. It is desirable to provide training to community volunteers in dune regeneration techniques so that they can contribute to effective weed control, particularly through hand weeding and other non-chemical methods. The control methods recommended by CALM (1999) for some of the priority weed species along the Joondalup coast are shown in Table 8.

Weed control efforts should utilise the city's resources, contractors and community efforts, according to the approaches to weed control in Section 5.3.5. As a general guide, species-led control should be undertaken first, followed by site-led control and then resource-led control. Species-control will be appropriate for *Leptospermum laevigatum*, and a likely occurrence of *Malva dendromorpha*[4] in the Iluka area. The native *M. australiana* is not usually found on the mainland in the Perth metropolitan area (E. Rippey, pers. comm., April 2002), and generally has white flowers, unlike the specimen found, which had mauve flowers. The other likely species would be *M. linnaei*, which is also an introduced weed. Most of the foreshore is more suited to site-led control, with many opportunities for community participation in resource-led control, for example on foredunes. Each weed control site should be assessed according to which weed species are present, the time of year and available resources. In general, *High* priority weeds should be tackled first, followed by *Moderate* priority weeds.

[4] *Malva dendromorpha* was formerly known as *Lavatera arborea*. *Malva australiana* was formerly known as *Lavatera plebeia*. *Malva linnaei* was formerly known as *Lavatera cretica*.

Table 8: Control methods for priority weed species

Source: *Environmental Weed Strategy for Western Australia database - weedBase* (CALM, 1999)

Species	Method*				EWSWA Rating	Herbicide(s) and Application Rates	Timing	Control Notes and General Comments
	1	2	3	4				
Anagallis arvensis Pimpernel	✓	✓	✓		Moderate	Try Glyph/Roundup or Glean at 15g ha. Ally/Brsh do control this weed.		Competes with small herbs. Mainly a problem in moist badly disturbed areas when the plants become more vigorous. Therefore only worth controlling in these areas.
Arctotheca calendula Cape Weed	✓	✓	✓		Moderate	Glyphosate/Roundup knapsack 100 mL in 15L water or stronger solution on large plants. Lontrel 1 in 100 has been used successfully by Mains Road Dept. over 1 year old direct seeded woody seedlings and mature bush. Do not use Lontrel over sensitive plants such as orchids. Seek further advice before using.		Mainly in disturbed areas where extra water/nutrients encourage lush growth. Generally only worth controlling in these areas.
Arctotheca populifolia Dune Capeweed	✓	✓	✓		Moderate	Glyphosate/Roundup knapsack 100 mL in 15L water or stronger solution on large plants, Pulse can be added.		Only control where no danger of blow out.
Avena barbata Wild Oats	✓	✓	✓	✓	Moderate	Use 2L Fusilade per ha for blanket and spot spraying. Easy to control.	No timing given – probably best to spray before flowering to prevent seed set.	
Briza maxima Blowfly Grass	✓	✓	✓	✓	Moderate	Sertin or other similar herbicides at 2L/ha.	No timing given – probably best to spray before flowering to prevent seed set.	Easy to control.
*Method 1 - Hand Weeding, Pulling, Digging; Method 2 - Herbicide Wipe, Stem Injection or Cut Stump; Method 3 - Spot Spraying; Method 4 - Blanket Spraying								

Species	Method*				EWSWA Rating	Herbicide(s) and Application Rates	Timing	Control Notes and General Comments
	1	2	3	4				
Briza minor Shivery Grass	✓	✓	✓	✓	Moderate	Sertin or other similar herbicides at 2L ha.		Easy to control.
Cakile maritima Sea Rocket	✓	✓	✓		Moderate	No specific information on herbicide control available. Suggest Roundup/Glyphosate.	When actively growing	Competes with native plants. Only control amongst native plants when erosion by wind will not be a problem.
Carpobrotus edulis Pigface	✓				Moderate	No specific information on control using herbicides. Pull up and destroy.		Usually in bare or disturbed areas. Competes with native plants. Very difficult to control with herbicides.
Ehrharta calycina Perennial Veldt Grass			✓	✓	High	Easy to control with Fusilade at 4L/ha. or similar herbicides e.g. Sertin, Targa. Spot spray at 2L/ha to run off.	Treat during winter, early spring, before seeds set and before plants dry out (thus avoiding fire hazard).	Remove small infestations by hand, cut roots as close to culms as possible with a sharp knife. Heavy infestations may require mop up spray the following year. Smothers small plants and competes with natives. A serious fire hazard.
Euphorbia peplus Petty Spurge	✓	✓	✓		Moderate	No specific information on herbicide control available. Suggest Sprayseed try 10-15mL in 10L water + 0.25% wetter, knapsack, when actively growing or Roundup/Glyphosate 75-100mL in 15L water.	When actively growing	Only tends to be a problem in highly disturbed areas, where it gets extra moisture and nutrients. Pull out small populations before seeding. Wear gloves to protect your skin from the plants' sap.
Euphorbia terracina Geraldton Carnation Weed	✓	✓	✓		High	Spray-Seed 200,10-15mL in 10L water + 0.25% wetter.	Early winter.	Common and serious weed of road verges, coastal heath, Tuart woodlands and grazing lands throughout south-west WA.
Lagurus ovatus Hare's Tail Grass	✓	✓	✓	✓	High	Spray with Fusilade or similar herbicide at 2-4L/ha..	Winter.	Competes with native plants
Malva dendromorpha Tree Mallow	✓	✓			High	No specific information on herbicide control . Suggest cut stump method, Roundup Glyph. or Brushoff, Velpar, Garlon, when actively growing.	When actively growing	Replaces the native *Lavatera pleibeia.*
*Method 1 - Hand Weeding, Pulling, Digging; Method 2 - Herbicide Wipe, Stem Injection or Cut Stump; Method 3 - Spot Spraying; Method 4 - Blanket Spraying								

Species	Method*				EWSWA Rating	Herbicide(s) and Application Rates	Timing	Control Notes and General Comments
	1	2	3	4				
Leptospermum laevigatum Victorian or Coastal Tea Tree	✓	✓	✓		High	Spot spray small plants. Can use Garlon, Grazon or Velpar with care. If cut at ground level no need for herbicide.	When actively growing	Replaces native species. Produces large amounts of seed. Killed by fire. Hand pull small seedlings. Spot spray small plants. Paint cut stump when actively growing. Apply Roundup/Glyphosate straight after cutting. Remove tops which may have seeds still attached. Check following years for new seedlings.
Oenothera drummondii Beach Evening Primrose	✓	✓	✓		Moderate	No specific information on herbicide control. Suggest high rates of Glyph/Rndup, plus Pulse when actively growing.	When actively growing	Mainly in highly disturbed areas. May only be able to control in sheltered areas or away from dunes where erosion from wind is unlikely.
Pelargonium capitatum Rose Pelargonium		✓	✓		High	No specific data for herbicide control. Suggest Ally/Brush-off at 5g/ha. Glyphosate 1 in 100 in early September gave some control, add wetting agent. Try with wick applicator. Repeat applications may be necessary.	Ally/Brush-off: August, September. Glyphosate: June to October	Smothers small native plants. Colonises natural bare sandy areas, therefore destroys natural habitat of burrowing snakes. Difficult to control. Pull plants in autumn/winter when soil is damp. Plant will reshoot if stem is broken at or below ground level. Secondary weeding is important but good control can be achieved.
Tetragonia decumbens Sea Spinach	✓	✓	✓		Moderate	No specific information for herbicide control available. Suggest high rates of Glyphosate/Roundup when actively growing.	When actively growing	Usually in highly disturbed areas. Only try to control in areas where there is no danger of erosion by wind (blowout). May be best to use a herbicide as the dead plant helps to reduce erosion. Do not confuse with native species. The native *Tetragonia implexicoma*, has less fleshy leaves and darker, narrower stems than *Tetragonia decumbens*.
*Method 1 - Hand Weeding, Pulling, Digging; Method 2 - Herbicide Wipe, Stem Injection or Cut Stump; Method 3 - Spot Spraying; Method 4 - Blanket Spraying								

Species	Method*				EWSWA Rating	Herbicide(s) and Application Rates	Timing	Control Notes and General Comments
	1	2	3	4				
Trachyandra divaricata Strapweed	✓	✓	✓		Mild	Difficult to remove by hand due to regrowth and new germinants. Spot spraying with Ally/Brushoff in summer/autumn at 5g ha gives 95% control, spraying at same rate the following year gives 100% control. Wiping with 1g to 1L water eg 10L solution per ha gives 85 - 90% control.	Summer and autumn with follow up one year later.	Usually found in disturbed areas. Only control in areas where this is no danger of erosion by wind.
*Method 1 - Hand Weeding, Pulling, Digging; Method 2 - Herbicide Wipe, Stem Injection or Cut Stump; Method 3 - Spot Spraying; Method 4 - Blanket Spraying								

Note: Glyphosate concentrations given are for Glyphosate 360.

A key to the herbicides and their active ingredients is provided below:

Product Name	Active Ingredient	Product Name	Active Ingredient
Ally Ò	Metsulfuron-methyl	Pulse ®	polyalkyloxylated dimethylpolysiloxane
Amitrol T ®	Amitrole + ammonium thiocynate	**Roundup** Ò	glyphosate
Brushoff Ò	Metsulfuron-methyl	**Spray-Seed** Ò	paraquat + diquat
Dalapon Ò	2,2-DPA	**Sertin** Ò	Sethoxydim
Fusilade Ò	Fluazifop-butyl	**Targa** Ò	quizalofop-p-ethyl
Glean Ò	Chlorsulfuron		

Please note:

The products highlighted in **bold typeface** above have been registered for the above specific purposes with the National Registration Authority for Agricultural and Veterinary Chemicals. Other products may be registered via an Off-Label Permit, which allows use of registered or non-registered products for specific purposes.

It is necessary that the application of herbicides be in accordance to labelling requirements or the manufacturers Materials Safety Data Sheet and must be undertaken by personnel trained in the use of herbicide chemicals. The application of any herbicide for purposes not specified on the labelling requires an Off-Label Permit from the National Registration Authority in Canberra. The application of herbicides must also be in accordance with water catchment restrictions.

Along the tracks and pathways, at least in the short term it is likely that weed control will continue to be implemented due to concerns over fuel loading in the event of a fire. Concerns over the death of native plants due to unintentional spraying of herbicide could be allayed by ensuring more selective application of herbicide. Plant control by spraying may assist with fire break installation and dual use path access.

In areas where there is a high risk of fire (generally along heavily frequented sections of the dual access pathway in medium and high public recreation zones where levels of weed invasion are high, and where vegetation is present on only one side of the fence), consideration could be given to creating a low fuel zone on the fenced dune. This could involve removing all weeds and native vegetation from a 20-30 cm band on the fenced side of the dune, treating the area to remove as much weed reproductive matter as possible, and covering the area liberally with mulch, or other low-fuel materials such as succulent ground covers like *Carpobrotus virescens*. This approach would need to be carefully done in conjunction with planting and weed removal along the "edge" of the low fuel zone. In the short term, regular maintenance and follow-up weed control would be required to ensure that the low-fuel zone remained weed-free, and did not represent a blight on the natural landscape of the dunes. In the long term, creation and maintenance of a low fuel zone around the fence would result in reduced dependence on herbicide use along pathways. The low fuel zone approach could be used experimentally along short stretches of the fencing.

Weed species that were not included in the list of priority species should not be excluded from control activities on that basis. These species should be included in any weed control programme as species which could be controlled if resources allow, but which are not of as high a priority for control.

Weed control on coastal dunes where priority weeds are a dominant component of the flora requires careful management to prevent dune erosion and blowouts. *Moderate* rated weeds should only be controlled where there is no danger of erosion. *High* rated weeds should be controlled as appropriate, using herbicide so that the dead plant material remains to bind soil. Native ground-stabilising species should be planted as soon as possible following weed control. Temporary erosion control measures such as placement of tritter, brush and mulch will be necessary until native plants have grown to a sufficient size.

Consideration should be given to establishing weed monitoring quadrats in areas subject to weed control to assess the effectiveness of control methods, and any new weed species will be recorded and incorporated into the weed control programme as appropriate. If the city's resources can not be used for this task, it could be a useful educational exercise for school, TAFE or university groups.

Weed control will be assisted by reducing the disturbance factors that enable weeds to establish and proliferate. Measures aimed at reducing the impact of disturbance factors include access management, fire management, erosion control and ecological restoration.

6.3.3 Fire Management

Fire management is of primary importance particularly in the Burns Beach area which has heathland of high conservation value and is becoming more at risk from fire as development in the area increases. An adequate firebreak is therefore needed to compartmentalise possible fire outbreaks and lessen the risk of the entire area of heathland being devastated by fire. The construction of this should follow existing tracks where possible to minimise damage caused through construction. A fire management plan should be created for the coastal foreshore area that details specific strategies to minimise the risk of wildfire and enable an effective response in the event of a wildfire outbreak.

Zone	Management Strategy	Priority	Implementation
Conservation	• Develop Fire Management Plan.	High	Immediately
	• Initiate fuel reduction and weed control.	High	Seasonally
	• Construct and maintain east-west firebreak in high risk areas (Burns Beach heathland).	High	Immediately
	• Initiate 'fire watch' program.	Medium	Continuous
	• Initiate public education program.	Medium	Continuous
	• Assess and rehabilitate burnt areas.	Medium	If required
	• Install signage.	Low	Immediately
Low Intensity Recreation	• Develop Fire Management Plan.	High	Immediately
	• Initiate fuel reduction and weed control.	High	Seasonally
	• Initiate 'fire watch' program.	Medium	Continuous
	• Initiate public education program.	Medium	Continuous
	• Assess and rehabilitate burnt areas.	Medium	If required
	• Install signage.	Low	Immediately
Medium Intensity Recreation	• Develop Fire Management Plan.	High	Immediately
	• Initiate fuel reduction and weed control.	High	Seasonally
	• Initiate 'fire watch' program.	Medium	Continuous
	• Initiate public education program.	Medium	Continuous
	• Assess and rehabilitate burnt areas.	Medium	If required
	• Install signage.	Low	If required
High Intensity Recreation	• Develop Fire Management Plan.	High	Immediately
	• Initiate fuel reduction and weed control.	High	Seasonally
	• Assess and rehabilitate burnt areas.	Medium	If required
	• Install signage.	Low	If required

6.3.4 Disease

Honey fungus *(Armillaria luteobalbina)* is not treatable so management strategies are primarily associated with minimising plant stress and avoiding the spread of infected plant material. A summary of the management strategies for plant disease is given in Table 9.

Management strategies for reducing plant stress involve the ready availability of the plants' needs and prevention of adverse external factors. The use of appropriate revegetation techniques and minimisation of disturbance is of high importance particularly in the initial stages of plant development. Following is a list of techniques that can act to minimise plant stress and increase survival rates of seedlings.

- Tree guards help maintain a moist microenvironment and shelter from wind stress and sandblasting;
- Mulch primarily discourages weed growth but also helps trap nutrients and water and stabilises sand;
- Weed control is necessary to prevent competition;
- Reticulation may be required in some areas to alleviate water stress;
- Soil preparation – fertiliser may sometimes be required to provide enough nutrients; and
- Brushing stabilises sand and deters disturbance by people.

The level of care required depends on the species. When planting hardy dune binding grasses such as *Spinifex* species, techniques to stabilise the sand and combat wind stress and water loss will be more important than maintaining nutrient levels. In these areas placement of brush or tritter is all that will be necessary. When planting heath species in more sheltered and stable areas, additional methods such as tree guards and reticulation may be used depending on the situation and the budget.

Movement of soil and plant material from one area to another should be avoided so as to minimise the possibility of spreading pathogens. Plant material or soil adhering to equipment should also be removed before using the equipment in other areas.

Table 9: Summary of management strategies for plant disease

Zone	Management Strategy	Priority	Implementation
Conservation	• Clean equipment after use • Minimise plant stress	High High	Continuous Continuous
Low Intensity Recreation	• Clean equipment after use • Minimise plant stress	High High	Continuous Continuous
Medium Intensity Recreation	• Clean equipment after use • Minimise plant stress	High High	Continuous Continuous
High Intensity Recreation	• Minimise plant stress	High	Continuous

6.3.5 Feral Animals

Rabbit control should be undertaken as a priority on Burns Beach as the vegetation in this area is in excellent condition. If a fire occurred in this area, regeneration would be impeded, as rabbits would consume most of the young seedlings. Rabbit control should also be undertaken in areas of rehabilitation and revegetation for the same reason. Currently rabbit control is limited to Pindone baits and rabbit-proof fencing surrounding areas where rabbits have been removed. The use of Pindone baits may not be appropriate, particularly considering non-target native fauna may also be affected. If rabbit infestation is high, mesh or wire tree-guards may be necessary. A summary of the management recommendations for feral animals is given in Table 10.

Table 10: Summary of management strategies for feral animals

Zone	Management Strategy	Priority	Implementation
Conservation	• Investigate suitable method of rabbit control in areas of high quality coastal heath (particularly Burns Beach)	High	As soon as possible
Low Intensity Recreation	• Mesh tree guards around seedlings	Medium	If required
Medium Intensity Recreation	• Mesh tree guards around seedlings	Medium	If required
High Intensity Recreation	• Mesh tree guards around seedlings	Medium	If required

6.3.6 Access and Recreation

Fencing should be used to control access and exclude people from sensitive areas. Recreational use of natural areas should be confined to beach areas, paths, lookouts and designated zones. Pedestrian traffic across sand dunes, in blow outs and on limestone cliffs should be minimised by fencing these areas, with accompanying signage to encourage people to use the paths to improve the condition of coastal areas. A summary of the management strategies for access and recreation is given in Table 11.

Table 11: Summary of management strategies for access and recreation

Zone	Management Strategy	Priority	Implementation
Conservation	• Fence all conservation areas • Brush unofficial access points • Implement appropriate signage	High Medium High	Immediately As required Immediately
Low Intensity Recreation	• Fence all conservation areas • Brush unofficial access points • Implement appropriate signage • Provide access paths to beach and recreational areas	High Medium High Low	Immediately As required Immediately As required
Medium Intensity Recreation	• Fence all conservation areas • Brush unofficial access points • Implement appropriate signage • Provide access paths to beach and recreational areas	High Medium High Medium	Immediately As required Immediately After priority tasks complete
High Intensity Recreation	• Fence all conservation areas • Brush unofficial access points • Implement appropriate signage • Provide access paths to beach and recreational areas	High Medium High Medium	Immediately As required Immediately Immediately

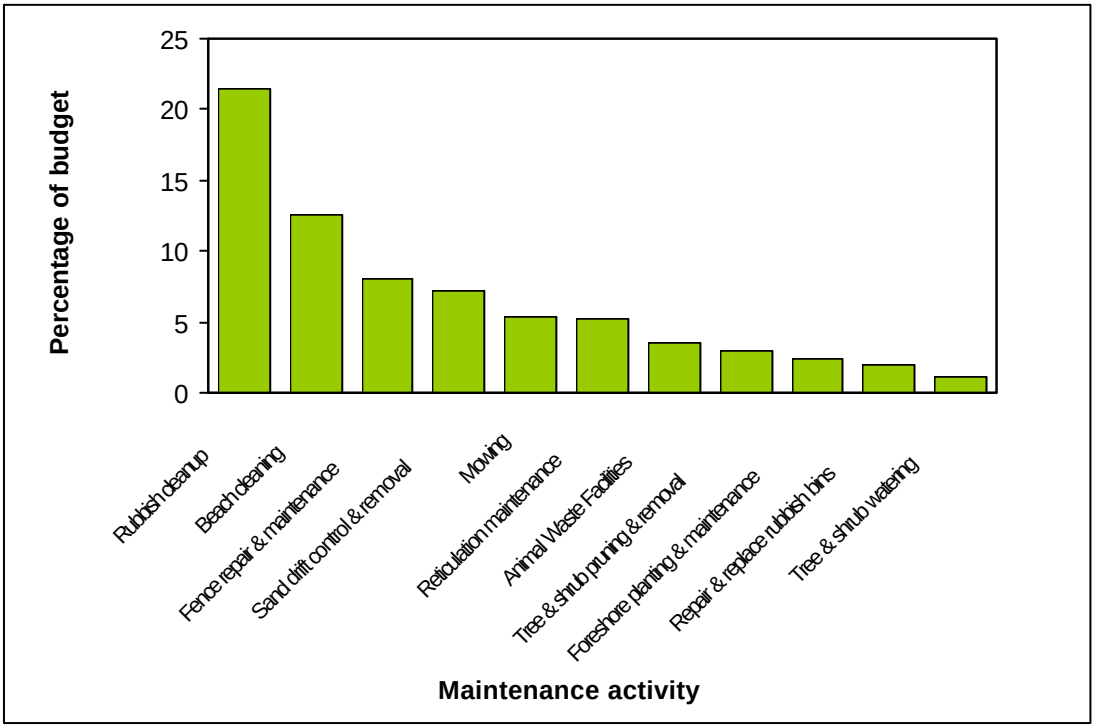
6.4 Costs

6.4.1 Current Maintenance Expenditure

The maintenance expenditure from July 2001 to July 2002 for work carried out on the foreshore between Burns Beach and Hillarys Animal Beach totalled around $80,000. This is just for particular jobs and does not take into account other areas of expenditure such as administration, construction and reticulation. As this information is necessarily incomplete, a percentage of the total expenditure for each job detail was calculated and represented graphically for comparison (Figure 8). Maintenance activities that represented less than one percent of the expenditure were not represented and included:

- Mulching
- Brush cutting vegetation
- Spot weed control
- Beach levelling
- Repair and replacing information signs
- Fencing - post and rail, bollard repairs and maintenance
- Park furniture repairs and maintenance
- Vandalism & graffiti
- Bore and pump maintenance
- Storm clean up
- Sand stabilisation

Figure 8: Proportion of maintenance activities carried out on foreshore between Burns Beach and Hillarys Animal Beach



The maintenance activities and proportion of budget spent show that the allocation of funds toward conservation is very low. Of the activities listed above foreshore planting and maintenance, mulching and spot weed control together, involve less than 5% of the total expenditure. Although mulching and planting activities are generally carried out by Corrective Services where there is only the cost of the supervisor and materials, it appears that there needs to be additional funds set aside for these and additional activities.

Fencing maintenance and repair consumes about 8-9% of expenditure and is an ongoing cost. A large proportion of these activities are also carried out by Corrective Services which indicates the scale of fence maintenance that needs to be undertaken. It is anticipated that if these activities were taken over by fencing contract repairers or city works crews the costs would increase substantially.

6.4.2 Cost Estimates

At present volunteer groups carry out some rehabilitation and weed removal in natural areas along the foreshore. The costs associated with the current level of rehabilitation for non-volunteer groups are:

- Contract herbicide application (2 men + vehicle) $100/hour
- Corrective Services supervisor $30/hour
- Coastal fencing contractor $7.50/metre

Rehabilitation of the areas identified in Figures 4 and 5 will require additional labour and expertise than supplied by volunteers. The costing presented further on in this report assumes that plants will be bought and planted (ie not seeded), and community volunteers will participate in planting. The extent of rehabilitation required will depend on the areas of bushland condition. The estimate below has divided the coastal area into distinct zones, and calculated costs for the rehabilitation of each zone. The areas of each category of bushland condition in each zone are shown in Table 12.

Table 12: Area of each bushland condition category per sector

Sector	Very Good to Excellent	Fair to Good	Poor	Very Poor	Erosion & Blowouts	Total Area
Iluka Foreshore	26.24	8.21	5.49	0.68	0.38	**41.00**
Ocean Reef	7.72	6.04	4.24	0.75	0.00	**18.76**
North Mullaloo	18.95	8.03	2.18	1.58	3.60	**34.35**
Mullaloo	1.50	6.24	3.30	1.01	0.00	**12.05**
Whitfords	8.98	7.97	2.74	0.12	0.45	**20.26**
Pinnaroo Point	1.75	8.50	13.28	1.90	0.35	**25.79**
Hillarys Beach	6.25	2.29	2.32	0.67	0.68	**12.21**
Sorrento Beach	0.00	0.00	4.02	0.70	0.17	**4.90**
Marmion Beach	0.33	1.66	1.12	0.58	0.23	**3.92**
Total Area	**71.73**	**48.94**	**38.69**	**8.00**	**5.87**	**173.23**

The estimated costs associated with the projected scope of work in the identified zones are shown in Tables 13 and 14, and Figure 9. These figures assume that plants will be bought and planted (ie not seeded), and labour will be contracted. Use of volunteer labour may cut the figure down by about half.

Table 13: Cost of professional rehabilitation per square metre

Condition	Very Good to Excellent	Fair to Good	Poor	Very Poor	Erosion and Blowouts
Establishment			$5.00	$6.00	$8.00
After 1st Year	$0.10	$0.50	$2.00	$3.00	$3.00
After 2nd Year	$0.10	$0.10	$1.00	$1.20	$1.20
After 3rd Year	$0.10	$0.10	$0.50	$0.50	$0.50
Years thereafter	$0.10	$0.10	$0.10	$0.10	$0.10

Table 14: Cost estimates for rehabilitation for each sector of foreshore

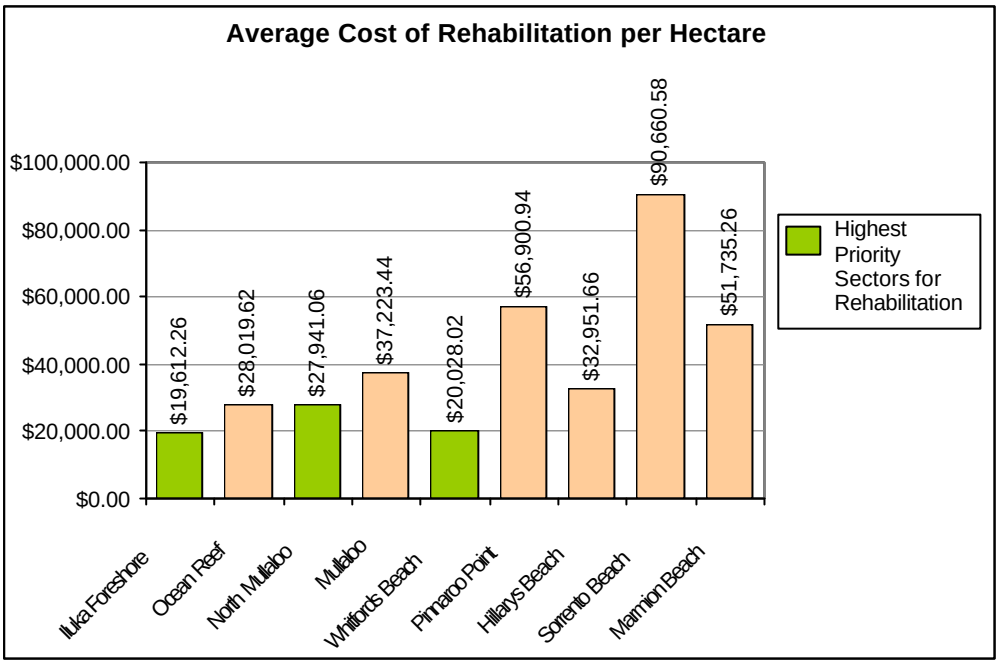
The following cost estimate is based on the ideal scenario in which enough labour, money and resources were available to target all of the Joondalup foreshore within a five year timeframe. The costs below would more likely be spread over greater than five years, for example by staggering the years of establishment for each sector, or by staggering the establishment for certain areas within each sector (ie, for Pinnaroo Point as an example, starting rehabilitation of *Poor* areas in 2002/2003, followed by *Very Poor* areas in 2003/2004 and so on).

SECTOR	**CONDITION RATING**					**EST. COST**
Iluka Foreshore *Area: 41.00 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	**Cost Per Year**
Establishment	$0.00	$0.00	$274,495.00	$41,022.00	$54,696.00	$370,213.00
After 1st Year	$26,235.20	$41,058.00	$109,798.00	$20,511.00	$20,511.00	$218,113.20
After 2nd Year	$26,235.20	$8,211.60	$54,899.00	$8,204.40	$8,204.40	$105,754.60
After 3rd Year	$26,235.20	$8,211.60	$27,449.50	$3,418.50	$3,418.50	$68,733.30
Years thereafter	$26,235.20	$8,211.60	$5,489.90	$683.70	$683.70	$41,304.10
					Total Cost over Five Years	**$804,118.20**
Ocean Reef *Area: 18.76 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$212,245.00	$45,240.00	$0.00	$257,485.00
After 1st Year	$7,724.50	$30,192.00	$84,898.00	$22,620.00	$0.00	$145,434.50
After 2nd Year	$7,724.50	$6,038.40	$42,449.00	$9,048.00	$0.00	$65,259.90
After 3rd Year	$7,724.50	$6,038.40	$21,224.50	$3,770.00	$0.00	$38,757.40
Years thereafter	$7,724.50	$6,038.40	$4,244.90	$754.00	$0.00	$18,761.80
					Total Cost over Five Years	**$525,698.60**
North Mullaloo *Area: 34.35 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment*	$0.00	$0.00	$109,185.00	$94,722.00	$288,328.00	$492,235.00
After 1st Year	$18,951.70	$40,136.00	$43,674.00	$47,361.00	$108,123.00	$258,245.70
After 2nd Year	$18,951.70	$8,027.20	$21,837.00	$18,944.40	$43,249.20	$111,009.50
After 3rd Year	$18,951.70	$8,027.20	$10,918.50	$7,893.50	$18,020.50	$63,811.40
Years thereafter	$18,951.70	$8,027.20	$2,183.70	$1,578.70	$3,604.10	$34,345.40
					Total Cost over Five Years*	**$959,647.00***

In the North Mullaloo Sector, significant efforts have already been put into rehabilitation of degraded areas, particularly areas mapped as “erosion and blowouts”. For this reason, the estimated cost of Establishment for eroded areas can be subtracted from the total cost of Establishment, resulting in a total estimated cost of $203,907.00 in the first year of rehabilitation, and a total estimated cost over five years of $671,319.00.

SECTOR	CONDITION RATING					EST. COST
Mullaloo *Area: 12.05 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$164,965.00	$60,408.00	$0.00	$225,373.00
After 1st Year	$1,498.50	$31,208.00	$65,986.00	$30,204.00	$0.00	$128,896.50
After 2nd Year	$1,498.50	$6,241.60	$32,993.00	$12,081.60	$0.00	$52,814.70
After 3rd Year	$1,498.50	$6,241.60	$16,496.50	$5,034.00	$0.00	$29,270.60
Years thereafter	$1,498.50	$6,241.60	$3,299.30	$1,006.80	$0.00	$12,046.20
					Total Cost over Five Years	**$448,401.00**
Whitfords *Area: 20.26 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$136,760.00	$7,122.00	$36,224.00	$180,106.00
After 1st Year	$8,980.10	$39,842.50	$54,704.00	$3,561.00	$13,584.00	$120,671.60
After 2nd Year	$8,980.10	$7,968.50	$27,352.00	$1,424.40	$5,433.60	$51,158.60
After 3rd Year	$8,980.10	$7,968.50	$13,676.00	$593.50	$2,264.00	$33,482.10
Years thereafter	$8,980.10	$7,968.50	$2,735.20	$118.70	$452.80	$20,255.30
					Total Cost over Five Years	**$405,673.60**
Pinnaroo Point *Area: 25.79 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$663,975.00	$114,258.00	$27,904.00	$806,137.00
After 1st Year	$1,751.30	$42,523.00	$265,590.00	$57,129.00	$10,464.00	$377,457.30
After 2nd Year	$1,751.30	$8,504.60	$132,795.00	$22,851.60	$4,185.60	$170,088.10
After 3rd Year	$1,751.30	$8,504.60	$66,397.50	$9,521.50	$1,744.00	$87,918.90
Years thereafter	$1,751.30	$8,504.60	$13,279.50	$1,904.30	$348.80	$25,788.50
					Total Cost over Five Years	**$1,467,389.80**
Hillarys Beach *Area: 12.21 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$116,160.00	$40,278.00	$54,272.00	$210,710.00
After 1st Year	$6,252.00	$11,441.50	$46,464.00	$20,139.00	$20,352.00	$104,648.50
After 2nd Year	$6,252.00	$2,288.30	$23,232.00	$8,055.60	$8,140.80	$47,968.70
After 3rd Year	$6,252.00	$2,288.30	$11,616.00	$3,356.50	$3,392.00	$26,904.80
Years thereafter	$6,252.00	$2,288.30	$2,323.20	$671.30	$678.40	$12,213.20
					Total Cost over Five Years	**$402,445.20**
Sorrento Beach *Area: 4.9 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$200,955.00	$42,270.00	$13,960.00	$257,185.00
After 1st Year	$0.00	$0.00	$80,382.00	$21,135.00	$5,235.00	$106,752.00
After 2nd Year	$0.00	$0.00	$40,191.00	$8,454.00	$2,094.00	$50,739.00
After 3rd Year	$0.00	$0.00	$20,095.50	$3,522.50	$872.50	$24,490.50
Years thereafter	$0.00	$0.00	$4,019.10	$704.50	$174.50	$4,898.10
					Total Cost over Five Years	**$444,064.60**
Marmion Beach *Area: 3.92 ha*	***Very Good to Excellent***	***Fair to Good***	***Poor***	***Very Poor***	***Erosion and Blowouts***	
Establishment	$0.00	$0.00	$55,905.00	$34,758.00	$18,472.00	$109,135.00
After 1st Year	$334.40	$8,294.50	$22,362.00	$17,379.00	$6,927.00	$55,296.90
After 2nd Year	$334.40	$1,658.90	$11,181.00	$6,951.60	$2,770.80	$22,896.70
After 3rd Year	$334.40	$1,658.90	$5,590.50	$2,896.50	$1,154.50	$11,634.80
Years thereafter	$334.40	$1,658.90	$1,118.10	$579.30	$230.90	$3,921.60
					Total Cost over Five Years	**$202,885.00**
Total Cost over Five Years with Professional Labour						**$5,660,323.00**
Total Cost minus cost of Establishment for eroded areas in North Mullaloo						$5,371,995.00

Figure 9: Average "per hectare" costs of rehabilitation in each sector



6.4.3 Funding

An increase in funding levels will be necessary to rehabilitate dunes and control weeds in coastal areas to the level that is required. As the management authority for the Joondalup coastal area, the City of Joondalup will be responsible for seeking funds for rehabilitation and weed control projects in the area, as well as allocating enough funds at the yearly budgeting stage for implementation of the recommendation outline in this report.

There are a number of external sources of funding in the form of grants and employment and training programmes, which are described below. Funds can also be sought from the major stakeholders in the area including the Water Corporation the State Energy commission of WA, the Ministry of Transport and the Ministry of Sport and Recreation. Property developers, marinas and coastal industries can also be approached for assistance and sponsoring of coastal improvement projects. Relevant State Government bodies can also be approached for funds such as the South West Development Commission, and the Regional Parks section of CALM is the area is officially included within a regional park. A list of previous Coastcare grants within the City of Joondalup is presented in Appendix Four.

Coasts and Clean Seas and Coastcare

Coasts and Clean Seas is the coastal and marine component of the Natural Heritage Trust. Funding is available for a variety of projects, with the emphasis on practical "hands on" projects aimed at better managing natural resources and restoring, conserving and enhancing the coastal and marine environment. The next round of applications for funding should close around May 2002.

Coastcare is a major component of Coasts and Clean Seas and to date has been the primary source of external funding for rehabilitation works in the Joondalup coastal area. Coastcare supports direct community involvement in the management of coastal and marine areas. Its focus is on practical actions and on-ground works that tackle the causes of

environmental degradation. In Western Australia, Coastcare is delivered as a joint programme with the Western Australian Governments Coastwest Grants Programme. Coastcare projects should be submitted jointly by a community group and the local management authority. It is understood that some of the dune rehabilitation work currently being undertaken within the study area is supported by a Coastcare grant. Activities in the Joondalup coastal foreshore that could qualify for funding include dune stabilisation and revegetation, weed control, erosion control, enhancing sustainable tourism and recreation, and improving access to the coast.

Bushcare

Bushcare is a programme administered by Environment Australia and funded by the Natural Heritage Trust. It provides funding to projects which can demonstrate:

- A regional perspective;
- Activities are aimed at conservation of bushland;
- Projects are community-based;
- Have a 1-3 year time frame; and
- Detailed programmes have been developed for projects.

Further emphasis is placed on areas that contain significant ecological communities and/or species, which are afforded protection under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. It is also necessary to demonstrate that the funding can achieve a demonstrable improvement in bushland condition.

Gordon Reid Foundation

The Lotteries Commission's Gordon Reid Foundation for Conservation provides funding to help community groups conserve natural habitats and biodiversity. There are two grant categories, Minor Grants for up to $5000 and Major Grants for grants over $5000, which are available to incorporated organisations. Only local government authorities and non-profit community groups can apply for this type of funding. Projects that have previously received funding support from the Foundation include revegetation, direct seeding, fencing remnant vegetation, and controlling weeds, feral animals, disease and fire.

Greening WA

Greening WA Inc works with the community to protect and restore native vegetation at a greater rate than the rate of decline. Greening WA is particularly concerned with restoring degraded farmland, neglected wetlands and natural bushland. Greening WA is a member of the national Greening Australia federation. It is resourced through the Federal Government's Bushcare program, the Western Australian government, corporate sponsors and members. Greening WA are involved with administering a number of programs for revegetation and protection of remnant vegetation, such as the National Corridors of Green Program. Greening Australia also provides plants, seeds and materials to school groups in the metropolitan area called 'Grow us a Home'.

Community Environment Art and Design Funding

Community Environment Art and Design (CEAD) was established as a funding programme by the Australia Council for the Arts to stimulate and support innovative approaches to

designing the built and natural environment. This program has recognised the fundamental link between the quality of the environment and the cultural life of communities, and encourages direct community involvement in planning for the future. The design, construction and placement of interpretive signage throughout the foreshore area could qualify as a CEAD project and receive funding, provided that local artists and/or community members are involved.

Corporate Sponsorship

There are a number of bushland management activities currently funded (either jointly or wholly) by corporate parties, such as Alinta Gas, Western Power, Alcoa, Woodside, insurance companies and banks. This avenue for funds for implementing works should be explored more fully.

References

Joondalup Coastal Foreshore Natural Areas Management Plan

Ahern J (1995) Greenways as a Planning Strategy. *Journal of Landscape Urban Planning* 33: 131-156.

Alan Tingay and Associates (1998) *A Strategic Plan for Perth's Greenways*. Prepared for Environment Australia, Ministry for Planning, Department of Conservation and Land Management, Western Australian Municipal Association, Department of Environmental Protection, Water and Rivers Commission, Main Roads Western Australia, Swan Catchment Centre, Conservation Council, Greening Western Australia and Australian Trust for Conservation Volunteers.

Alan Tingay and Associates, Ewing Consulting Engineers, Feilman Planning Consultants and Ian Lovegrove (1996) *Quinns Rocks Estate Stage 1 – Foreshore Management Plan.* Unpublished report for Silverton Limited.

Bradley J (1971) *Bush Regeneration*. Mosman Parklands and Ashton Park Association, Sydney.

Bradley J (1988) *Bringing Back the Bush: the Bradley method of bush regeneration*. Landsdowne Press. Sydney.

Buchanan R (1989) *Bushland Regeneration: Recovering Australian Landscapes*. NSW: TAFE.

Churchward HM and McArthur WM (1980) Landforms and Soils of the Darling System Western Australia. In Department of Conservation and Environment, *Atlas of Natural Resources, Darling System, Western Australia.* Department of Conservation and Environment, Perth, Western Australia.

City of Stirling (1984) *City of Stirling Coastal Report.* City of Stirling Council

City of Wanneroo (1989) *Foreshore Management Plan for Mullaloo Point*. City of Wanneroo Town Planning Department.

City of Wanneroo (1990) *Pinnaroo Point Foreshore Management Plan.* City of Wanneroo.

City of Wanneroo Town Planning Department (1991a) *Hillarys Beach – Hillarys Park Foreshore Management Plan.* City of Wanneroo.

City of Wanneroo Town Planning Department (1991b) *Whitfords Beach Foreshore Management Plan.* City of Wanneroo.

Coast*Wise* (2001) *Draft Scarborough Environs Study.* Report prepared for the City of Stirling.

CoastWise (1999) *Metropolitan Beach User Survey: 7 February 1999*. Unpublished report prepared for the City of Joondalup.

CoastWise (1998) *Coastal Planning Study for the Town of Cambridge* Unpublished report prepared for the Town of Cambridge

Department of Parks and Reserves (1991) *City of Stirling Management Plan Trigg Bushland Reserve (Trigg Regional Open Space)* Unpublished Report for the Town of Cambridge.

Department for Planning and Infrastructure (2001) *Coastal Planning Program – Draft Status of Coastal Planning in WA 2001/02*. Unpublished report.

Department of Conservation and Environment (1983) *The Darling System – System 6. Part II: Recommendations for Specific Localities*. Department of Conservation and Environment, Western Australia.

Department of Conservation and Land Management (CALM) (1999) *Environmental Weed Strategy for Western Australia*. Includes *weedBase* – a digital weed database. Department of Conservation and Land Management, Perth, Western Australia.

Department of Conservation and Land Management (2002) *Marmion Marine Park* [Online]. Available: http://www.calm.wa.gov.au/national_parks/marmion.html [2002, February 1].

Department of Conservation and Land Management. (1999) *Environmental Weed Strategy for Western Australia.* Department of Conservation and Land Management, Perth, Western Australia.

Dixon B and Keighery G (1995) Weeds and their control. In: Scheltema M and Harris J (Eds) *Managing Perth's Bushlands.* Pp. 65-141. Greening WA, Perth, Western Australia.

Environmental Protection Authority (1994) *Proposal to change land use affecting System Six areas and lakes protected under the Environmental Protection Policy to Urban, Industrial, Special Uses and transportation purposes, to be reflected in the major Metropolitan Region Scheme Amendments for the South West Corridor. Report and Recommendations of the Environmental Protection Authority.* EPA Bulletin 746. EPA, Perth, Western Australia.

Fire and Rescue Service of Western Australia (1997) *Incident Statistics 1996/97*. Published by Government of Western Australia, WA Fire Brigades Board and Fire and Rescue Service, Perth, Western Australia.

Fire and Rescue Service of Western Australia (1998) *Incident Statistics 1997/98*. Published by Government of Western Australia, WA Fire Brigades Board and Fire and Rescue Service, Perth, Western Australia.

Gibson N, Keighery BJ, Keighery GJ, Burbridge AH and Lyons MN (1994) *A Floristic Survey of the Southern Swan Coastal Plain.* Unpublished report for the Australian Heritage Commission. Prepared by Department of Conservation and Land Management and the Conservation Council of Western Australia (Inc.).

Government of Western Australia (2000) *Bush Forever*. Department of Environmental Protection, Perth, Western Australia.

Halpern Glick Maunsell (1995) *Public Environmental Review for: Proposed Residential Development of the Western Cell, Lot 2 Burns Beach.* Unpublished report for Burns Beach Property Trust

Heddle EM, Loneragan OW and Havel JJ (1980) Vegetation complexes of the Darling System Western Australia. In Department of Conservation and Environment, *Atlas of Natural Resources Darling System Western Australia*. Department of Conservation and Environment, Perth, Western Australia.

Hussey BMJ, Keighery GJ, Cousens RD, Dodd J and Lloyd SG (1997) *Western Weeds*. The Plant Protection Society of Western Australia, Victoria Park.

Kaesehagen DB (1995) Bushland Condition Mapping in *Invasive Weeds and Regenerating Ecosystems in Western Australia*. G Burke (ed), Institute for Science and Technology Policy, Murdoch University.

Keighery GJ and Keighery BJ (1992) *Flora of the Burns Beach Coastal Reserve*. Unpublished survey for the Department of Conservation and Land Management, Como, Western Australia.

Kimseed Environmental (2000) *Australian Native Seed Catalogue 2000/2001*. Kimseed Environmental Pty Ltd.

Oma VPM, Clayton DM, Broun JB and Keating CDM (1992) *Coastal Rehabilitation Manual*. Department of Agriculture Bulletin 4248. Perth, Western Australia.

Rippey E and Rowland B (1995) *Plants of the Perth Coast and Islands*. University of Western Australia Press, Nedlands.

Scott and Furphy Engineers Pty Ltd Landscape Division (1979) *Coastal Nodes – Development Plan Report.* Report prepared for the Shire of Wanneroo, Perth, Western Australia.

Shire of Wanneroo (1985) *Ocean Reef Foreshore Management Plan*. Shire of Wanneroo.

South Metropolitan College of TAFE (nd) *Coastal Rehabilitation Techniques*. Unpublished course manual.

Tract (WA) and Kinhill Engineers (1995) *Mullaloo – Ocean Reef Foreshore Management Plan.* Unpublished report prepared for the City of Wanneroo.

Woods PJ (1984a) *Local Coastal Management Plan –Wanneroo Sectors 2 and 3: Sorrento to Burns Beach.* Unpublished report for the Shire of Wanneroo.

Woods PJ (1984b) *Results of the Wanneroo Coastal Study with Draft Goal, Objectives and Recommendations for a Coastal Management Policy*. Unpublished report prepared for the Shire of Wanneroo.

Wycherley RR and Robley J (1983) The bush fire risk in the Perth Metropolitan Region. In: Moore S (Ed) *The Management of Small Bush Areas in the Perth Metropolitan Region*. Pp. 6-10. Proceedings of a seminar held on 20/09/83by the Department of Fisheries and Wildlife.

Appendix One:
Images of Priority Weed Species

Joondalup Coastal Foreshore Natural Areas Management Plan

Anagallis arvensis

Pimpernel

Description:

Anagallis arvensis is a hairless annual up to 40 cm high, with four-sided stems. The leaves are opposite, oval-shaped, and have no stalk. The flowers are held on a long, slender stalk, have five petals, and may be either red or blue, with a purple patch at the base of each petal (Rippey and Rowland, 1995).

Drawing by Elizabeth Rippey reproduced by permission from Rippey and Rowland (1995).

Arctotheca calendula

Cape Weed

Description:

Arctotheca calendula is an annual herb with a basal rosette of leaves. The leaves are up to 20 cm long and are often deeply lobed. The lower surface of the leaves are covered with white hairs. The solitary flowerheads are borne on a firm stalk (Rippey and Rowland, 1995).

Photo: Coralie Hortin. Reproduced from Flora Base.

Arctotheca populifolia

Dune Capeweed

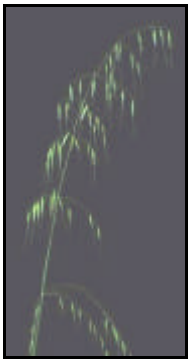
Description:

Arctotheca populifolia is a prostrate, many-branched annual or perennial. The plant has a covering of fine white hairs, with stems that form rosettes of fleshy silver-green leaves. The spherical yellow flowerhead is borne on a sturdy stalk (Rippey and Rowland, 1995).

Photos: Coralie Hortin and Rod Randall. Reproduced from Flora Base and Western Weeds (Hussey *et al*., 1997).

Avena barbata

Wild Oats



Description:

Avena barbata is an annual grass with a drooping, one-sided flower. *A. barbata* closely resembles another major weed, *A. fatua*, but differs in respect to the flowers. *A. fatua* has an upright, rather than drooping, inflorescence (Rippey and Rowland, 1995).

Photo: Rod Randall. Reproduced from Western Weeds (Hussey *et al*., 1997).

Briza maxima

Blowfly Grass

Description:

A tufted annual to 60 cm tall with leaves to 20 cm long (Rippey and Rowland, 1995). The species gets its common name from resemblance of the flowers to blowflies.

Detail of flowers and form of plant
Photos: John Dodd and Mack Seale. Reproduced from Flora Base.

Briza minor

Shivery Grass

Description:

Briza minor is an erect, densely tufted annual up to 50 cm tall with leaves to 15 cm long. The inflorescence is much-branched with small nodding spikelets (Rippey and Rowland, 1995).

Photo: Rod Randall. Reproduced from Western Weeds (Hussey *et al*., 1997).

Cakile maritima

Sea Rocket

Habit of Plant

Photo: Anonymous

Detail of flowers

Photo: Anonymous

Description:

Cakile maritima is a low, spreading annual herb. It is a very hardy plant, and is able to grow on beach sand below the foredunes and blowouts. The leaf is fleshy and highly variable. The flower is mauve, pink or violet (Rippey and Rowland, 1995).

Carpobrotus edulis

Pigface

Description:

Carpobrotus edulis is a succulent creeping perennial with stems 1-2 metres long and roots developing at the nodes. The plant has bright green, succulent leaves that are triangular in cross section. The yellow flower is 5 to 8 cm in diameter. The plant is difficult to distinguish from the native *Carpobrotus virescens* except during flowering. The native species has a pink flower (Rippey and Rowland, 1995).

Flower and leaves

Photo: Rod Randall. Reproduced from Western Weeds (Hussey *et al*., 1997).

Ehrharta calycina

Perennial Veldt Grass

Description:

Ehrharta calycina is a tufted perennial to 80 cm tall. The inflorescence is a drooping erect panicle of reddish-purple flowers, 7 to 22 cm long. *E. calycina* flowers in spring, and is a common and widespread weed of roadsides and bushland on sandy soils (Hussey *et al*., 1997).

Photo: Stan Armstrong. Reproduced from Flora Base.

Euphorbia peplus

Petty Spurge

Description:

Euphorbia peplus is an annual plant up to 300 mm high with a milky sap. The leaves are alternate. The flowerheads grow from the axil of floral leaves. *E. peplus* can be confused with *E. terracina*. One way to tell the difference is that the leaves of *E. peplus* are broad, with stalks, while the leaves of *E. terracina* are narrow, with no stalk (Rippey and Rowland, 1995).

Detail of leaves

Photo: Rod Randall. Reproduced from Western Weeds (Hussey *et al*., 1997).

Euphorbia terracina

Geraldton Carnation Weed

Description:

Euphorbia terracina is a hairless perennial to 80 cm, much branched at the base. The leaves are linear, 1 to 4 cm long. The flowers are yellow-green, produced at the end of stems. When cut, the plant produces a milky, irritating and very toxic sap. (Hussey *et al*., 1997).

Photo: John Dodd. Reproduced from Flora Base.

Lagurus ovatus

Hare's Tail Grass

Description:

Lagurus ovatus is an erect, grassy annual to 30 cm tall. The leaf blades are flat and softly hairy. The plant flowers between late winter and summer, producing dens, silky white inflorescences (Rippey and Rowland, 1995).

Photo: Rod Randall. Reproduced from Hussey *et al* (1997).

Leptospermum laevigatum

Victorian or Coastal Tea Tree

Description:

Leptospermum laevigatum is a tall shrub up to 3 metres high. The leaves are firm, and oval shaped to elliptic, 20-30 mm long. The flower is white and solitary.

Photo: Rod Randall. Reproduced from Flora Base.

Malva dendromorpha

Tree Mallow

Description:

Malva dendromorpha, previously known as *Lavatera arborea* is a biennial plant between 1 and 3 metres tall. The leaves are hairy, circular to ovate, with 5 to 7 lobes and up to 90 mm long. The flower, about 50 mm across, is pink-purple. This plant has displaced the native *M. australiana* (formerly known as *L. plebeia*) in many areas. The native *M. australiana* generally has white flowers, although sometimes they may be mauve. The leaves of *M. australiana* are also circular, but tend not to be as deeply lobed as *M. dendromorpha*.

Drawing by Elizabeth Rippey reproduced by permission from Rippey and Rowland (1995).

Oenothera drummondii

Beach Evening Primrose

Description:

Oenothera drummondii is a prostrate, white-haired perennial that dies back in winter. The leaves are variable in size. The flower is large, up to 7 cm across, and bright yellow.

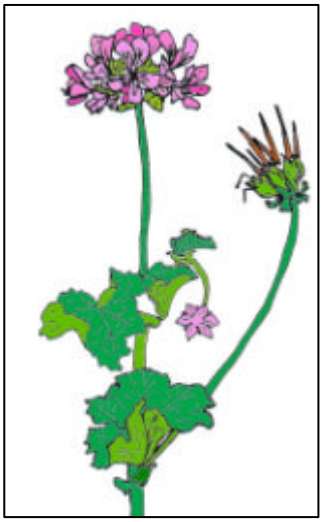
Photos: Stan Armstrong. Reproduced from Flora Base.

Pelargonium capitatum

Rose Pelargonium

Description:

Pelargonium capitatum is "a softly hairy, low spreading shrub, growing to 1 metre high in sheltered sites. The leaf is almost circular, lobed, about 70 mm broad and aromatic when crushed. 3-20 flowers are present in an umbel. The petals are pink with crimson markings" (Rippey and Rowland, 1995: p.203).

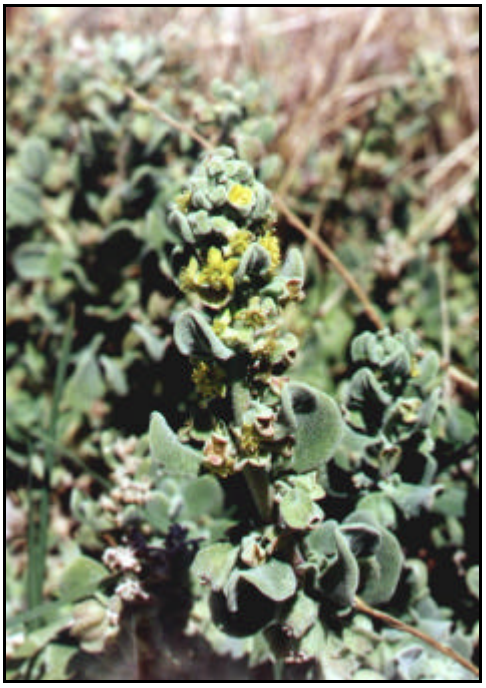


Detail of plant

Sketch: Lesley Thomas

Tetragonia decumbens

Sea Spinach



Detail of flowers
Photo: Anonymous

Habit of plant
Photo: Anonymous

Description:

Tetragonia decumbens is "a succulent trailing herb with thick pale stems. The leaves are obovate, fleshy and glistening with surface water-storage cells. The leaf margins turn backwards towards the prominent midrib on the lower surface." (Rippey and Rowland, 1995: p.231). The plant has an extensive root system, and can cover several square metres of sand, giving it a role in dune stabilisation.

Trachyandra divaricata

Strapweed

Description:

Trachyandra divaricata is a tuberous plant, to 0.5 m high. The ribbon-like leaves, to 0.5 m long by 5-10 mm wide, are slightly fleshy and lie on the ground in sprawling masses. The flower is white, with petals with brown stripes and a yellow spot at the base. When mature, the dry, branched infloresence is moved around by wind, scattering seed (Rippey and Rowland, 1995).

Photo: Keith Eddington, Kym Lego and Brenda Mowe. Reproduced from Flora Base.

Appendix Two:
Results of Aboriginal Site Register Search

Joondalup Coastal Foreshore Natural Areas Management Plan

Appendix Three:
Bradley Method of Bush Regeneration

The aim of bush regeneration by the Bradley method is the systematic removal of weeds to allow native plants to re-establish themselves when and where they choose. This method does not involve replanting – simply the gradual removal of weeds so that no large openings are made. This makes the Bradley method ideal for many situations, such as where native plants are able to colonise the site by seeds or vegetative means, areas sensitive to erosion and areas likely to be over-used.

UNDERLYING PRINCIPLES

1. Always work from areas with native plants towards weed-infested areas.

This makes good ecological sense. If you are relying on natural regeneration then choose areas that will contain the maximum number of existing native plants and native plant seeds, and minimal weed seeds and vegetative reproductive organs of weeds.

2. Make minimal disturbance.

Application of this principal depends on the native species to regenerate. Many plant communities (both weeds and native) need disturbed and sunlit soil for successful regeneration. However, by following the 1st principle above, any weed regeneration should be minimised. Any soil that is disturbed should be returned in its original layers, thus ensuring that any native seed stored in the soil will still be on top. This principle also applies to the application of natural plant mulch in the work area – where a gap is left as a result of weeding, it is recommended that mulch from surrounding areas be added to the gap. This helps to minimise weed regeneration.

3. Let native plant regeneration dictate the rate of weed removal.

The ability to follow this principle may depend on the amount of time and money committed to a particular project. If few weeds and many native plants regenerate, or if the ground remains weed free, little time will need to be spent re-weeding a site, allowing time to be spent on other sites. If masses of weeds regenerate then a lot of time will be required re-weeding so that regenerating native plants can flourish.

DEVELOPING WORK PLANS

1. Prevent deterioration of good areas.

Start by removing weeds scattered through otherwise clean bush. Practically no follow up work will be needed, but it should be checked once or twice a year.

2. Improve the next best area.

Once you are confident you have prevented deterioration of better condition bush, you can start work on thicker patches of weed. Choose a place you can visit easily and often, where thick native growth is pushing up against weeds, preferably no worse than one weed species to every two native plant species. Start with a strip approximately 12 feet wide and no longer

than can be managed with monthly weeding days. If the area to be cleared of weeds runs up a slope which may erode, clear a number of smaller patches instead.

3. Hold the advantage gained.

Resist the temptation to push deeper into the weeds before regenerating natives have stabilised each cleared area. The natives do not need to be very tall, but they usually need to form an almost complete ground cover. Weeds will always nearly keep germinating until this is achieved. These newly regenerated areas are most vulnerable to weed reinvasion and so must be re-weeded as required. If weeding occurs adjacent to the regenerating area prior to sufficient new cover light from adjacent cleared patches can affect the regeneration of natives.

4. Cautiously move into the really bad areas.

When new growth coming up consists almost entirely of native plants with only a few weeds among them, it is safe to move deeper into the weeds. Keep working along the regeneration boundary, making new clearings smaller as the weeds get more dense.

WEEDING TECHNIQUES

1. Disturb the soil as little as possible.

All tools used for weeding programmes should be small, such as a broad boning knife, trowels, secateurs, pliers (for pulling roots), loppers, hatchet and small saws. This recommendation is based on the belief that using small tools will cause minimum soil disturbance and minimal damage to the roots and shoots of nearby native plants.

2. Sweep back the mulch surface.

Any weeding will disturb the ground litter and soil will be exposed. Repair the damage as you go, by pushing back as much mulch as possible. It is often helpful to sweep aside mulch prior to removing large plants, so that it can easily be redistributed when you have finished removing the plant.

3. Mulch with the weeds themselves.

Weeds removed can be used to add to existing mulch. In dry areas leaving the weed with its roots exposed will be sufficient to kill it. In moist areas, hanging the weeds on nearby native vegetation will allow them to dry out and die. Some items are unsuitable for mulch, and these are removed from the site. Such items include bulbs and tubers, plants that root at every node and free-seeders with ripe seed.

4. Watch where you put your feet.

Be careful how you move through the bush. A small weeding party moving through thick bush single file can open up a track. Efforts should be made to not walk on the same paths all the time, and to watch where you walk to ensure you are not trampling native vegetation.

Appendix Four:
Coastcare Grants within the City of Joondalup

Joondalup Coastal Foreshore Natural Areas Management Plan

Year	Project Title	Primary Applicant	Community Applicant	Approved Funding	Agency Applicant	Project Summary
1997	Mullaloo Beach - Dune Rehabilitation & Restoration Project	City of Joondalup	Friends of Marmion Marine Park	$19,750.00	City of Wanneroo	Project objectives include rehabilitation and restoration of significant dunes and facilitating safe public access to the beach and along the coast; enhancing this recreational amenity and its environmental sustainability. Action proposed to achieve this includes fencing, branching and rehabilitation, to protect the sensitive dunes and direct people away from hazardous areas. Fencing is essential to combat the cause of dune degradation; unrestricted access through dunes. Branching is a proven and cost-effective measure which dissuades incompatible uses and facilitates natural regeneration. Utilising local species, replanting is an efficient method of enhancing the coastal environment and extending habitat for coastal fauna. Complementary activities funded by the City include upgrading carpark and beach access. Also, a lookout and dual-use path connecting the present coastal path will be established to facilitate recreation, tourism, awareness and enjoyment of the coast and adjacent Marine Park. The sensitive design, following existing tracks, is located a safe distance from the cliffs. Informative signage to increase appreciation of the area will encourage appropriate use. The project area will be maintained by the City and subject to community monitoring. The competent project team includes skilled professionals and the local community, an appropriate partnership for long term preservation of our coast.
1998	Dune Stabilisation/Rehabilitation, Hillarys	The Church of Latter-Day Saints	The Church of Latter-Day Saints	$10,665.00	City of Joondalup	Stabilise foredunes, repair fences, remove exotic weed species, rehabilitate dunes, replace signage.

Year	Project Title	Primary Applicant	Community Applicant	Approved Funding	Agency Applicant	Project Summary
2000	Monitoring And Maintaining Hillarys Beach Coastal Environment	Padbury Primary School	Padbury Primary School Community	$9,600.00	City of Joondalup	Due to vandalism and erosion occurring in the Hillary's Beach coastal area the Padbury Primary School Community wishes to collect data, monitor beach profile, litter and water temperature (CALM Marine Community Monitoring Program). Rehabilitate dune areas (City of Joondalup). Raise community awareness and stewardship of coastal area by presenting findings through presentations at shopping centres, signage at the Marina, community radio, newspaper reports and other local networks. Develop a Coastcare website for Padbury Primary School. Employ a project officer to oversee planning and monitoring of programs, collection, presentation, preservation of data.
2000	Dune Stabilisation And Education Project, Mullaloo	City of Joondalup	Joondalup Community Coast Care Forum	$11,000.00	City of Joondalup	Rehabilitate dune areas immediately north of the Mullaloo Surf Life Saving Club, but leave approx. 10m by 10m area as an educational feature of what a rehabilitated and degraded dunal system looks like. This area will be supplemented with before and after photographs on interpretation board(s). These will also include information about the local history of the area. Three pathways will be closed and some light poles that are inappropriate will also be removed. One walkway will be realigned.
2100	Perth Coastal Interpretation Trail	The Church of Jesus Christ of Latter Day Saints	The Church of Jesus Christ of Latter Day Saints	$40,909.00	City of Joondalup	Erect innovative interpretation signage at 7 locations down the coast from Burns Beach to Fremantle. Perth is one of few cities with a remarkable diverse and easily accessible coastline. The continuous coastal dual use pathway is currently an underutilized resource to educate its many users about their immediate coastal environment. Local communities and cities will design and erect signage to showcase coastal processes such as erosion and accretion of beaches, local ecosystems, aboriginal heritage, local sites of interest within the vicinity and coastal management initiatives. Re-vegetation activities will also be undertaken in the vicinity of the chosen sites to further involve the local community.